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## The Effect of Wet Strength Resins on the Dimensional Stability of Paper

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THE EFFECT OF WET STRENGTH RESINS  
ON THE  
DIMENSIONAL STABILITY  
OF  
PAPER |

A dissertation  
submitted to the faculty  
of  
Western Michigan University  
by

Robert Carey, Jr.  
|)

In partial fulfillment of the prerequisite for the degree  
of  
Bachelor of Science

January, 1961

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## INTRODUCTION

For many grades of paper, dimensional stability is very important in order for the paper to serve its specific purpose. Included in this category are such papers as map paper, template paper, printing papers, and chart paper. Dimensional stability may be improved by subjecting the fibers to less refining, but strength and other properties suffer as a result. Thus, any material which could be added to the fibers to increase dimensional stability would be welcomed by the paper industry.

The purpose of this thesis is to establish whether a particular type of material, wet strength resins, will improve dimensional stability. Wet strength resins can be added in the beater and are, therefore, easily added without special equipment.

Three wet strength resins were chosen to be investigated; Parex 607, a melamine-formaldehyde resin; Uformite 700, a urea formaldehyde resin; and Kymene 557, a new resin on the market. It was decided to add these three resins to the pulp in various percentages to determine any effect they might have upon dimensional stability.

## Historical and Theoretical Survey

### Dimensional Stability

A well-known feature of paper is the dimensional changes which occur when there is a change in the moisture content of the paper. In many converting processes, as well as in other fields of use, it is impossible to maintain a constant moisture content in paper. The moisture content of paper is dependent upon the humidity of the surrounding air, and thus it is not necessary for paper to come into direct contact with free water in order for it to cause difficulties in applications where dimensional stability is of importance.

Calkins (1) points out that the changes in dimension caused by changes in the relative humidity of the surrounding atmosphere is of particular concern. These changes result from two chief causes. The first cause is the changing of dimensions of the individual fibers. For example, cotton shows an increase of from twelve to fifteen per cent in diameter with a change of from zero to ninety per cent in relative humidity. However, there was a very slight increase in length. However, this is not the most important cause for dimensional instability since in most sheets of paper there is a large amount of empty space which the enlarging fibers can occupy.

The second cause of dimensional instability, Calkins continues, is the relaxation of strains in the paper when the moisture content is increased. As he explains, a sheet of paper is not a uniform homogeneous material, but is composed of individual fibers which have been formed together into a wet mass, in a reasonably random orientation. As this mass is being formed, fibers are bent and twisted while they are flexible (as a result of being wet). This mass is then pressed and dried under tension. As the fibers dry, they shrink, they become stiffer, and as water is removed they are pulled toward one another by surface tension effects and form bonds--presumably hydrogen bonds--between hydroxyl groups on areas on various fibers close enough for this phenomenon to take place. Differential shrinkage takes place; strains formed by fibers drying, bending, and being placed under tensions are "frozen" in by the conditions on the paper machine--machine direction tension from the pull of the reel, and tension caused by forces of internal shrinkage being resisted by felt pressure. This sheet when subjected to high humidity will show expansion because the moisture will tend to release the bonds that hold the sheet together.

Calkins lists a number of points to support the above explanation;

1. Soft, unbeaten papers show low expansivities. (Plenty of space to expand and little bonding.)
2. Paper recycled several times between high and low humidities shows lower expansivity because some strains are permanently removed.
3. Paper from the edges of a paper machine shows greater expansivity than paper from the center. It is well known that paper on the edges shrinks more than paper from the center.
4. Fillers or plasticizers cut expansion. Besides reducing the effective amount of fiber, they reduce bonding.

Tongren (2) attributes the changes of dimension with changes in relative humidity to the fact that cellulose is a hygroscopic material. It takes up moisture from the surrounding atmosphere until an equilibrium has been established. Conversely, cellulose will give up moisture to a dry atmosphere. In either case the cellulosic material paper will tend to change its dimensions, to expand as it takes up moisture vapor, or to contract as it gives up moisture vapor.

From the above explanations, it is reasonable to believe that dimensional stability could be improved by the addition of a material to hold the bonds although the fiber-to-fiber bonds are relaxed or a material to make the fiber bonds impervious to water.



### Wet Strength Resins-History

Britt (3) traces three phases in the development of urea-formaldehyde and melamine-formaldehyde, two of the better known wet strength producing resins.

The first of these phases, also mentioned by an anonymous author (27), occurred in the period 1938-1942 and was the use of water soluble urea-formaldehyde condensation products of a low degree of polymerization as a tub size or surface application treatment.

The next phase was the development of resins, which could be added directly to the papermaking stock and which would be absorbed by the fiber. The melamine-formaldehyde resin introduced at that time (1943) and which has since become so widely known throughout the paper industry possesses an inherent affinity for fiber by virtue of being a cationic colloid. The urea resins introduced at that time did not have this inherent affinity for fiber but could be precipitated upon the fiber by means of alum.

The third and most recent phase has been the development of urea resins which are naturally cationic and which will be absorbed by the fiber more efficiently and under a wider variety of conditions than formerly.

Melamine-formaldehyde was the first resin developed for the wet-strength treatment of paper by slush stock

addition. (4) This development followed a dramatic laboratory discovery--that the aging of an acidified melamine-formaldehyde solution transformed the water soluble compound into a hydrophilic colloid which is absorbed quantitatively on negatively charged cellulosic fibers. This process was and still is practical even under conditions of extreme dilution.

#### Wet Strength Resins--Urea-Formaldehyde

Urea-formaldehyde resins are thermosetting resins which are made by the catalytic condensation of urea with formaldehyde and are characterized by their absorption of large amounts of water, causing them to swell and shrink with changes in moisture content.(5) Furthermore, they are dimensionally unstable in atmospheres of widely varying humidity, are resistant to hydrocarbons, organic solvents, and weak acids, but are attacked by alkalis and strong acids.

Urea-formaldehyde resins as well as melamine-formaldehyde resins are divided into two groups; anionic and cationic.(6) In turn, each group may be classified as low condensed, or approaching monomeric proportions, and high condensed. Both anionic and cationic resins may be obtained in modified forms.(7)

Alum must be used with anionic urea-formaldehyde as a mordanting agent to provide effective retention upon

the fiber, since stock suspensions possess a negative charge.(8) Meyers and Morin(9) showed that good performances cannot be obtained with these resins unless a three way interaction is obtained among the fibers, alum, and resin.

Cationic urea-formaldehyde is "tailor made" for versatility and ease of operation. Since it has an attractive charge for pulp, operating conditions need not be so carefully controlled and the use of alum is eliminated. On the other hand, care must be taken that the very same cationic properties that can aid retention does not hinder it.(10) This can happen if the pulp is only slightly anionic and the resin strongly cationic, so that the charge of the pulp may be reversed. With urea resins the charge density can be controlled so that this situation may be avoided.

Versatility of the urea-formaldehyde resins, either anionic or cationic, is enhanced by correacting other reagents into the polymer molecule producing modified resins. For example, when sodium bisulphite is used as the coreactant, a resin of extreme hydrophilic character is synthesized.(11) This permits retention of the water solubility of the resin at higher degrees of condensation than would otherwise be possible.

An anonymous author(12) lists a number of advantages

of urea-formaldehyde resins over melamine-formaldehyde resins:

1. Less expensive
2. Easier to use: The liquid urea-formaldehyde can be poured directly into the beater. Melamine must first be mixed with acid and aged four to eight hours.
3. Broke from urea is less of a problem. This is due to the fact that urea is slower curing than melamine.

As a general rule, urea is used in papers where a low degree of wet strength is wanted, as in paper towels.

Wet Strength Resins--Melamine-Formaldehyde

According to Battelle Memorial Institute, (5) melamine-formaldehyde resins are produced by the catalytic condensation of melamine with formaldehyde. The resins are thermosetting and are characterized by low water absorption, stability in humid atmospheres, and good electrical properties. They maintain their physical properties over wide variations in temperature. They have relatively low tensile and impact strengths, but they are nearly independent of temperature. They are decomposed by strong acids and alkalis, but are resistant to weak acids, weak alkalis, and to most of the organic solvents.

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A typical melamine-formaldehyde resin is described by Maxwell and Landes(13) as being positively charged, and easily attracted to cellulose fibers. In addition, the resin is equally effective on any form of cellulose fiber, although the results are more noticeable when used with a strong pulp. The presence of alum is not required to obtain good resin retention.

Fromm(22) suggests that melamine-formaldehyde resin be prepared for use by adding one pound to a gallon of dilute hydrochloric acid in the proportion of one mole of the resin to 0.8 mole of the acid; the concentration of hydrochloric acid in the total colloidal solution is approximately 1.5%. The corrosiveness of such a solution constitutes a problem, and for permanent installations, stainless steel and Saran tubing are recommended.

Melamine-formaldehyde offers a number of advantages over urea-formaldehyde: (12)

1. Greater resistance to acid hydrolysis.
2. Quicker cure--nearly 80% as it comes off the machine. Urea is often only 50%.
3. Lower shipping costs. Melamine is shipped in powdered form; urea comes in liquid form.
4. Longer shelf life--as long as five years without deterioration, whereas urea tends to "gel" after three to six months.

Other advantages have been offered by Fromm: (14)

1. No care in storage except keeping it dry.
2. Melamine appears to be equally effective in all types of pulp while urea resins seem to be more selective in their choice of pulps.
3. Easier to cure.
4. Under normal usage the melamine resin acid colloid appears to be completely retained by the fiber in contrast to urea resins, which probably have a retention ranging up to a maximum of 60%.

Melamine-formaldehyde resins are usually used where a high degree of wet strength is needed, as in maps.

#### Wet Strength Resins--Kymene 557

Hercules Powder Company has developed a new wet strength resin.(15) This new resin is designed for use in papermaking systems that operate under any pH condition. It is particularly effective in the pH range of 6 to 10. The efficiency of this wet strength resin, Kymene 557, increases slightly as pH increases. This is in contrast with cationic urea-formaldehyde resins and melamine-formaldehyde resins where increases in pH above 5.5 drastically reduce resin efficiency.

In many grades of paper--test liner and industrial wadding among them--the advantages of operating at

neutral or alkaline pH are customarily obtained. Delay in seeking these advantages has been due largely to the lack of satisfactory sizing and wet-strengthening chemicals. Many toweling mills find absorbency improved by operating under neutral or alkaline conditions. By using Kymene 557 for wet strength, toweling may be made on the alkaline side, thus retaining maximum absorbency of the sheet.

Kymene 557 is an entirely new resin of a type not previously used in paper to form wet-strength bonds. This new resin contains no formaldehyde, urea or melamine. Kymene 557 is a cationic water-soluble polymer with a nitrogen content (by Kjeldahl) of 12.8% dry basis.

Kymene 557 is supplied in water solution, ready to use. Its physical characteristics are:

Appearance . . . . .	pale amber liquid
Solids content . . . . .	10± 0.3%
Density, at 25°C . . . . .	1.026± 0.001
Viscosity (Gardner-Holdt scale). . . . .	A to B +
Nitrogen per cent, dry basis (Kjeldahl). . . . .	12.8%
Ionic type . . . . .	Cationic
Freezing point . . . . .	25°F. (-4°C.)
Shelf life (at or below 90°F). . . . .	100 days +
pH. . . . .	5.0± 0.1

Although Kymene 557 is an entirely new concept in

wet strength resins, its method of application is very similar to cationic modified urea-formaldehyde resins. Points of addition for Kymene 557 range from the beater to the fan pump. Generally, addition immediately after refining is preferred. When applied internally, retention is usually 70-80%.

The rate of cure of Kymene 557, like that of other wet strength resins, is a function of the conditions of drying on the paper machine. In many cases, the rate of cure after manufacture is higher than that of cationic urea-formaldehyde resins.

#### Wet Strength Resins--Effect on Dimensional Stability

Calkins (1) has stated that in order to increase dimensional stability the paper can be treated with some material that has the strength to hold stable dimensions although fiber bonds are relaxed. He goes on to say that one method of doing this is addition of resins to the paper. Conventional wet-strength addition probably tends to have that effect, but the amounts possible to add are insufficient.

Fromm(14) explains that melamine resin treatment does not give complete control over dimensional changes under varying conditions in relative humidity, but the effect is sufficient to be of value in offset, book, and bond grades. He says that the treated sheet will



react to humidity changes in much the same way as the untreated, but greater stability can be worked out by reducing the beating cycle to increase the fiber length, yet maintaining strength specifications by resin treatment. This idea is also held by George.(16)

George(16) also states that the effect of beater additions on dimensional stability is generally an adverse effect. No nonfibrous material which can be added to the pulp dispersion to bring about an appreciable reduction in expansion and contraction has yet been found. Bonds formed by resins or gums, states George, if they supplement rather than replace natural fiber-to-fiber bonds, generally increase hygroexpansivity.

Tout(17) holds the opposite view. He believes that dimensional stability is generally held to be closely allied to high wet strength and that it is fairly certain that the action of wet strength resins is to reduce the tendency of cellulose fibers to swell when wetted.

Wiltshire(18) has written that most papers, unless made from very free stock, will show substantial changes in dimension when subjected to varying conditions of relative humidity and that the effects of resins on dimensional stability were conflicting. He points out that American authors suggest that the reason for improved dimensional stability is that paper can now be made from

much freer stock and, because of the resin treatment, it can still meet the same strength specifications. Kumler(19) agrees with this explanation when he states that the mere addition of melamine resin in the manner and amounts used for wet strength has a negligible effect on dimensional stability unless in so doing the stock receives less beating.

Lorey and Libby (20) have studied the effect of (Uformite 700), a urea-formaldehyde resin, on dimensional stability. Due to the cationic nature of the resin, alum was not necessary for precipitation. However, the resin solution was adjusted to a pH of 4.5 with HCl, prior to immersion of the handsheets, to facilitate an effective cure during the drying period of twenty minutes at 105°C.

Only at 5.7 per cent resin retention were the dimensional changes decreased for the humidity increase from 50 to 75.8 per cent relative humidity, but the dimensional changes were decreased in all of the runs for the humidity increase from 75.8 to 96.6 per cent relative humidity. Urea-formaldehyde increases the hygroscopicity of the sheet, and thus more water is absorbed during the initial humidity rise, but above the 78.5 per cent relative humidity the moisture content prematurely approaches saturation and thus less expansion occurs.

Except for high humidities, the use of Uformite 700

resin for dimensionally stabilizing paper is limited because of its high hygroscopy. For papers used at high humidities it is a good stabilizer. The Uformite treated sheets showed no brittleness whatsoever.

<u>Conc. of Solution</u>	<u>% Resin Retained</u>	<u>% Expansion at</u>	
		<u>75.8% R.H.</u>	<u>96.6% R.H.</u>
0.0	0.0	.16	.31
3.0	5.7	.12	.26
8.4	16.6	.16	.24
16.0	35.6	.24	.27

Scribner, Shaw, O'Leary, and Messimer(21) showed that beater addition of 1-3 per cent melamine-formaldehyde resin to hardwood fibers caused a decrease in expansion of the resultant sheet with a 15 per cent relative humidity increase, while O'Leary, Scribner, and Messimer(22) discovered that beater addition of melamine-formaldehyde had variable effects upon expansion.

Nordman(23) found no significant effect on dimensional stability by addition of melamine-formaldehyde and urea-formaldehyde resins to paper stock, whereas Watson and Anderson(24) have patented a process whereby 2-3 per cent by weight of urea-formaldehyde or phenolic resins are added by impregnation to impart dimensional stability to paper.

## EXPERIMENTAL DESIGN

### Pulp Preparation

Beater runs were made using Weyerhaeuser bleached sulfite pulp, following the standard methods according to TAPPI. In each case the pulp was beaten to a freeness of 500 ml. and 250 ml. using the Canadian Standard Freeness Tester for all freeness determinations. This pulp was then used immediately or stored with a preservative until used.

### Handsheet Preparation

All handsheets were made using the Noble and Wood sheet machine. The resins were supplied in solution form and were added on the basis of percentage of dry resin based on moisture-free fiber. Three resins were used--Parez 607, Uformite 700, and Kymene 557.

Before the handsheets were formed, the pH was adjusted to obtain maximum resin efficiency. For Parez 607, the pH was adjusted to 4.5-6.5, for Uformite 700, 4.5, and for Kymene 557, 8.0-8.5. After pH adjustment, the resin was added in the amount of 0.25%, 0.50%, and 1.0% for each resin at each stock freeness. Four handsheets were made in each category, including control sheets to which no resin was added. The weight of each sheet was approximately 3 grams.

After the handsheets were prepared, they were cured by heating in an oven at a temperature dependent upon the resin used. The Parez 607 handsheets were heated for ten minutes at 250 F., the Uformite 700 handsheets were heated for ten minutes at 105 C., and the Kymene 557 handsheets were heated for one hour at 105 C. After curing, the handsheets were placed in a constant humidity room where they remained until ready to be tested.

#### Testing Procedure

After the handsheets were conditioned, they were tested for dimensional stability using the Neenah expansiometer. The samples for the test were cut into strips measuring  $8 \frac{1}{2}$  x 1 inch to obtain a length of 8 inches for testing. (After the first few samples, it was found to be more convenient to test 5 inch samples.) The expansiometer is very accurate, giving results to the nearest 0.0001 inch.

After the samples were placed in the expansiometer, a salt solution was placed in the tray provided to give the desired relative humidity. The first salt solution used was a saturated solution of potassium carbonate to give a relative humidity of 40-45%. The samples were allowed to stay in this humidity until a constant reading was obtained and then a saturated solution of sodium nitrite replaced the potassium carbonate to

obtain a relative humidity of about 70%. Again equilibrium was established and the micrometers were read to determine the change in sample length. This same procedure was followed with a third solution, potassium chromate, to obtain a relative humidity of 90-95%. After each reading, the actual relative humidity was measured using dry and wet bulb thermometers.

From the readings obtained, the change in length of the samples was determined with each change in humidity. From this change and the sample size, the per cent expansion was calculated.

## RESULTS AND DISCUSSION

### Kymene Resin

The results obtained using Kymene resin are tabulated in Table I where the per cent expansion is shown for the control samples, which were untreated, and the samples treated with the resin. The per cent expansion is shown for two relative humidity changes, 43-70% and 70-93%.

As can be seen from the results, the expansion tends to decrease with an increase in percentage resin for the 250 ml. freeness samples but increases with an increase in resin for the 500 ml. freeness samples. Also, with the higher relative humidity changes (70-93%), the per cent expansion is greater.

Table II shows a comparison between the treated and untreated samples. Here the ratio of untreated paper (Control) to the treated stock is shown to discover the effect the resin has on the expansion of the sheet. A value above 1.00 denotes an improvement in dimensional stability while a value below 1.00 denotes that the dimensional stability has decreased.

In the relative humidity range of 43-70% the 250 ml. freeness samples showed a general improvement in dimensional stability, with the exception of the sample treated with 0.25 % resin. This improvement was slight,

TABLE I

<u>Sample</u>	<u>R.H. Change</u>	<u>% Expansion</u>	<u>R.H. Change</u>	<u>% Expansion</u>
250 Control	43-70%	.128%	70-93%	.217%
250 Ky 0.25	43-70%	.167%	70-93%	.213%
250 Ky 0.50	43-70%	.127%	70-93%	.193%
250 Ky 1.0	43-70%	.114%	70-93%	.179%
500 Control	43-70%	.123%	70-93%	.182%
500 Ky 0.25	43-70%	.105%	70-93%	.169%
500 Ky 0.50	43-70%	.126%	70-93%	.183%
500 Ky 1.0	43-70%	.131%	70-93%	.190%

TABLE II

<u>Sample</u>	<u>R.H. Change</u>	<u>Control/Treated</u>	<u>R.H. Change</u>	<u>Control/Treated</u>
250 Control	43-70%	1.00	70-93%	1.00
250 Ky 0.25	43-70%	0.77	70-93%	1.02
250 Ky 0.50	43-70%	1.01	70-93%	1.12
250 Ky 1.0	43-70%	1.12	70-93%	1.21
500 Control	43-70%	1.00	70-93%	1.00
500 Ky 0.25	43-70%	1.17	70-93%	1.08
500 Ky 0.50	43-70%	0.98	70-93%	0.99
500 Ky 1.0	43-70%	0.94	70-93%	0.96



however. The 500 ml. freeness samples in the same relative humidity range showed a decrease in dimensional stability with an exception again in the 0.25% resin samples. The 250 ml. freeness samples showed more improvement with increasing resin content while the 500 ml. samples showed less improvement with increasing resin content.

The relative humidity range of 70-93% produced practically the same results as the 43-70% range, showing increasing improvement with increasing resin content for the 250 ml. freeness samples and showing an increasing adverse effect of the resin on the 500 ml. freeness samples.

In general, the Kymene resin appears to increase dimensional stability of stock beat to a freeness of 250 ml. and to decrease dimensional stability of a sheet with a freeness of 500 ml.

#### Urea-Formaldehyde Resin

Table III shows the results obtained using a urea-formaldehyde resin at the relative humidity ranges of 47-68% and 68-93%. The per cent expansion is given for each of the samples tested.

The expansion is greater for the relative humidity range of 68-93% and for the 500 ml. freeness samples as compared to the 250 ml. samples. This is to be expected, since dimensional stability decreases with an

TABLE III

<u>Sample</u>	<u>R.H. Change</u>	<u>% Expansion</u>	<u>R.H. Change</u>	<u>% Expansion</u>
250 Control	47-68%	.100%	68-93%	.210%
250 Uf 0.25	47-68%	.104%	68-93%	.296%
250 Uf 0.50	47-68%	.125%	68-93%	.266%
250 Uf 1.0	47-68%	.122%	68-93%	.296%
500 Control	47-68%	.126%	68-93%	.254%
500 Uf 0.25	47-68%	.110%	68-93%	.306%
500 Uf 0.50	47-68%	.136%	68-93%	.282%
500 Uf 1.0	47-68%	.136%	68-93%	.332%

TABLE IV

<u>Sample</u>	<u>R.H. Change</u>	<u>Control/Treated</u>	<u>R.H. Change</u>	<u>Control/Treated</u>
250 Control	47-68%	1.00	68-93%	1.00
250 Uf 0.25	47-68%	0.96	68-93%	0.71
250 Uf 0.50	47-68%	0.80	68-93%	0.79
250 Uf 1.0	47-68%	0.82	68-93%	0.71
500 Control	47-68%	1.00	68-93%	1.00
500 Uf 0.25	47-68%	1.15	68-93%	0.84
500 Uf 0.50	47-68%	0.93	68-93%	0.90
500 Uf 1.0	47-68%	0.93	68-93%	0.77

increase in refining.

The resulting change in expansion with resin treatment can be better demonstrated by Table IV, which shows the ratio of untreated sample expansion to treated sample expansion.

The results obtained for the urea-formaldehyde treatment indicate that the resin has an adverse effect upon the dimensional stability. That is, the dimensional stability decreases when the resin is added. For example, the 250 ml. freeness samples in the relative humidity range of 47-68% showed a sharp increase in expansion as the resin content increased. The 500 ml. freeness samples in this same range showed a decrease of expansion also, with the exception of the sample treated with 0.25% resin, which showed an improvement in dimensional stability.

In the 68-93% relative humidity range, both the 250 ml. and the 500 ml. freeness samples showed a decrease in dimensional stability by their higher expansions when resin was added.

With the exception of one sample, the urea-formaldehyde resin has shown an adverse effect upon the dimensional stability of the sheets, causing an increase in expansion above that of the control sheets.

#### Melamine-Formaldehyde Resin

The melamine-formaldehyde resin has tended to be most successful of the three resins tested in improving

TABLE V

<u>Sample</u>	<u>R.H. Change</u>	<u>% Expansion</u>	<u>R.H. Change</u>	<u>% Expansion</u>
250 Control	47-68%	.128%	68-93%	.232%
250 Me1 0.25	47-68%	.120%	68-93%	.290%
250 Me1 0.50	47-68%	.186%	68-93%	.214%
250 Me1 1.0	47-68%	.136%	68-93%	.228%
500 Control	47-68%	.234%	68-93%	.294%
500 Me1 0.25	47-68%	.120%	68-93%	.338%
500 Me1 0.50	47-68%	.118%	68-93%	.214%
500 Me1 1.0	47-68%	.156%	68-93%	.252%

TABLE VI

<u>Sample</u>	<u>R.H. Change</u>	<u>Control/Treated</u>	<u>R.H. Change</u>	<u>Control/Treat</u>
250 Control	47-68%	1.00	68-93%	1.00
250 Me1 0.25	47-68%	1.07	68-93%	0.80
250 Me1 0.50	47-68%	0.69	68-93%	1.08
250 Me1 1.0	47-68%	0.94	68-93%	1.02
500 Control	47-68%	1.00	68-93%	1.00
500 Me1 0.25	47-68%	1.95	68-93%	0.87
500 Me1 0.50	47-68%	1.98	68-93%	1.37
500 Me1 1.0	47-68%	1.50	68-93%	1.17

the dimensional stability of the sheets. This was not true in all categories of samples tested, as can be seen from Table V and Table VI.

The 250 ml. freeness samples in the 47-68% relative humidity range showed little improvement in dimensional stability. There was an increase in dimensional stability with the 0.25% resin sample, but the other two showed an opposite effect, causing a decrease in dimensional stability. In the 68-93% relative humidity range, however, the 0.25% resin sample showed an increase in expansion while the other two showed a decrease.

A very good improvement in dimensional stability was noted with the 500 ml. samples treated with resin in the 47-68% relative humidity range. In the 68-93% relative humidity range, an improvement was also noted, with the exception again of the sample treated with 0.25% resin.

## SUMMARY AND CONCLUSION

An important property of paper for certain grades is dimensional stability, or its ability to resist changes in dimensions with a change in moisture content of its surroundings. For this reason, wet strength resins were investigated for their effect upon this property.

Weyerhaeuser bleached sulfite pulp was beat to a freeness of 500 and 250 ml. and handsheets were made containing 0.25, 0.50, and 1.0 per cent dry resin based on moisture-free fiber weight. Three resins were used-- a Kymene resin, a urea-formaldehyde resin, and a melamine-formaldehyde resin. Handsheets were also made which contained no resin for control purposes.

After curing the resin, samples were cut to the desired size and placed in the Neenah expansiometer to measure the expansion of the samples with a change in relative humidity. The desired relative humidities were obtained using saturated salt solutions. The expansion was obtained by measuring the change in length of the samples with each relative humidity change. The per cent expansion was then calculated from the change in length of the samples and the original length of the samples.

The results that have been obtained are not conclusive. The Kymene resin has shown some improvement of dimensional stability but this was not consistent with all the samples. The urea-formaldehyde resin was very poor, with only one

sample showing an improvement in dimensional stability. The other samples showed a decrease in dimensional stability. The melamine-formaldehyde resin also showed improvement with many of the samples, but again it was not a consistent improvement.

In general, it cannot be said that wet strength resins improve dimensional stability of paper, although the Kymene and urea-formaldehyde resins did show some promise. The melamine-formaldehyde was very poor, probably due to the resin absorbing water itself because of its hygroscopic properties. At any rate, these resins would be worthy of further investigation in this area of use.

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