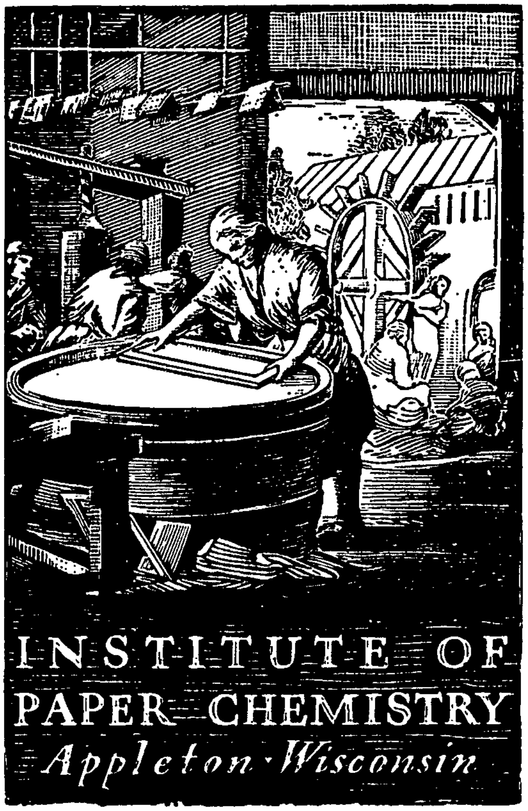
GENERAL



IMPROVED UTILIZATION OF CORRUGATOR PRECONDITIONING

Project 2696-21

Report One
to
FOURDRINIER KRAFT BOARD GROUP
OF THE
AMERICAN PAPER INSTITUTE

February 15, 1985

THE INSTITUTE OF PAPER CHEMISTRY
Post Office Box 1039
Appleton, Wisconsin 54912
Phone: 414/734-9251
Telex: 469289

February 15, 1985

TO
MEMBERS OF THE FOURDRINIER KRAFT BOARD GROUP
OF THE
AMERICAN PAPER INSTITUTE

Project 2696-21, Report One

IMPROVED UTILIZATION OF CORRUGATOR PRECONDITIONING

This project was directed to considering ways to improve preconditioner treatments to temporarily alter the MD properties of the medium in such a way as to promote fluting and end-use board quality. Past work at the Institute indicates that the medium loses about 40% of its compressive strength potentials in the MD and about 20% in the CD during the fluting operation. If we could reduce these losses it should be possible to effect savings on the manufacture of medium.

For this purpose we installed instrumentation to determine the effects of various steam shower and preheater conditions on the medium moisture, temperature and elastic stiffness of the medium as it enters the forming nip. With steam showers we were able to increase the moisture content of the medium web to about 12%. This compares with web moistures in the 4-7% range when only the preheater is used. The higher moistures reduced the MD stiffness which would be expected to promote better forming. As moisture contents increased up to about 10% the flat crush strength tended to increase by from 7-15% for 26-lb medium and by about 20% for a 33-lb medium. Generally the greatest reductions in stiffness of the medium were obtained with combinations of regular and special showers, particularly on heavy weight mediums.

The results also indicated that mediums differ in their stiffness response to preconditioning treatments. With some mediums greater temperature changes were required to affect stiffness. This may be due to furnish differences or other factors such as porosity and receptivity. This should provide insight on ways to improve the operational characteristics of medium.

After you have an opportunity to review the report we will appreciate any comments you may have.

Sincerely,

Bill

William J. Whitsitt
Group Leader
Containers Group
Paper Materials Division

cc: G. Baum

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

IMPROVED UTILIZATION OF CORRUGATOR PRECONDITIONING

Project 2696-21

by

William J. Whitsitt

and

Carl N. Smith

Report One

to

FOURDRINIER KRAFT BOARD GROUP

OF THE

AMERICAN PAPER INSTITUTE

February 15, 1985

TABLE OF CONTENTS

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

IMPROVED UTILIZATION OF CORRUGATOR PRECONDITIONING

SUMMARY

The objective of this project was to study ways to improve preconditioner treatments of medium to promote fluting and end-use board quality. For this purpose we installed instrumentation to determine the effects of various steam shower and preheater conditions on the medium moisture content, temperature, and elastic stiffness of the medium. Several alternative shower arrangements were tried.

In general, with the various steam shower arrangements we were able to increase the moisture content of the web to about 12%. This compares with web moistures in the 4-7% range when only the preheater is used. The higher moistures up to about 10% tended to increase flat crush by from about 7-15% for the 26-lb and by 20% for the 33-lb medium. However, most of this increase is accounted for by normal use of showers.

Generally, the greatest reductions in stiffness of the medium were attained with combinations of regular and special showers. This was more evident on heavy weight mediums.

The results also indicate that mediums differ in their stiffness response to preconditioning treatments. Some mediums appear to be more temperature sensitive, perhaps due to furnish, or other factors such as porosity and receptivity. This should provide insight on ways to improve the operational characteristics of medium.

INTRODUCTION

This project was directed to considering ways to improve preconditioner treatments to temporarily alter the MD properties of the medium to promote fluting and end-use board quality. Past work at the Institute indicates that in the fluting operation the medium loses about 40% of its compressive strength potentials in the MD and about 20% in the CD (1). If we could reduce the losses, we could effect significant savings in the manufacture of medium. This may be particularly true in the case of heavy-weight mediums.

The losses in compressive strength are dependent on three factors. They are (1) the basic properties of the medium, (2) the temporary alteration of these properties by preconditioning in the corrugator, and (3) the design and operation of the corrugator. The altered properties of the medium after preconditioning are critical because they determine how the medium will respond to the forming stresses. While the general effects of preconditioner heat and steam on runnability and bonding are known, there has been no quantitative information on how effective they are in modifying the medium properties to reduce compressive strength losses. Clearly, preconditioning is not very effective; otherwise, cold forming would not do well relative to hot forming. It is known that preconditioning requirements vary with the type of medium, speed, and corrugator design. This indicates that mediums differ in their response to presently used preconditioners.

The state of the medium after preconditioning depends on both the base properties of the medium and the effects of the preconditioning on the properties required for forming and bonding. Thus, there are two approaches to the improvement of fluting runnability and performance. One approach is to determine (1) what medium properties should be achieved in preconditioning using present mediums, (2) how closely we can approach the desired properties using present preconditioning practice, and (3) what changes in preconditioning would help promote fluting. A second approach is to determine papermaking ways to improve medium performance. The preconditioning potentials are the subject of this work.

BACKGROUND

The forming behavior of medium is mainly dependent on the MD tensile strength, stretch, Young's modulus (E_x), out-of-plane moduli (E_z and G_{xz}) and friction coefficient (1). Our recent work indicates that when the medium is bent to the flute contour, the severe bending strains are relieved by the simultaneous shear strains. The relative amounts of shear and bending strain will depend on E_x and G_{xz}. If G_{xz} is relatively high, the bending strains will be high and more compressive damage will occur if compensating increases in E_z are not made. In the extreme, flute fracture occurs when the bending tensions and tensions due to friction and the brake exceed the tensile strength and stretch of the medium.

Current research at the Institute indicates that the retention of compressive strength during fluting is approximately related to the elastic stiffnesses of the medium, basis weight, and density as follows (see also Fig. 1).

$$RR \propto 1 - (K/R)\ (E_xt/E_zt)^{1/4}\ (W/\rho) \tag{1}$$

Where RR = retention ratio (ratio of compressive strength of fluted to uncorrugated medium).

E_xt = MD elastic stiffness

E_zt = ZD elastic stiffness

W = Basis weight

ρ = Density

R = Radius of curvature of flute tips

K = Constant

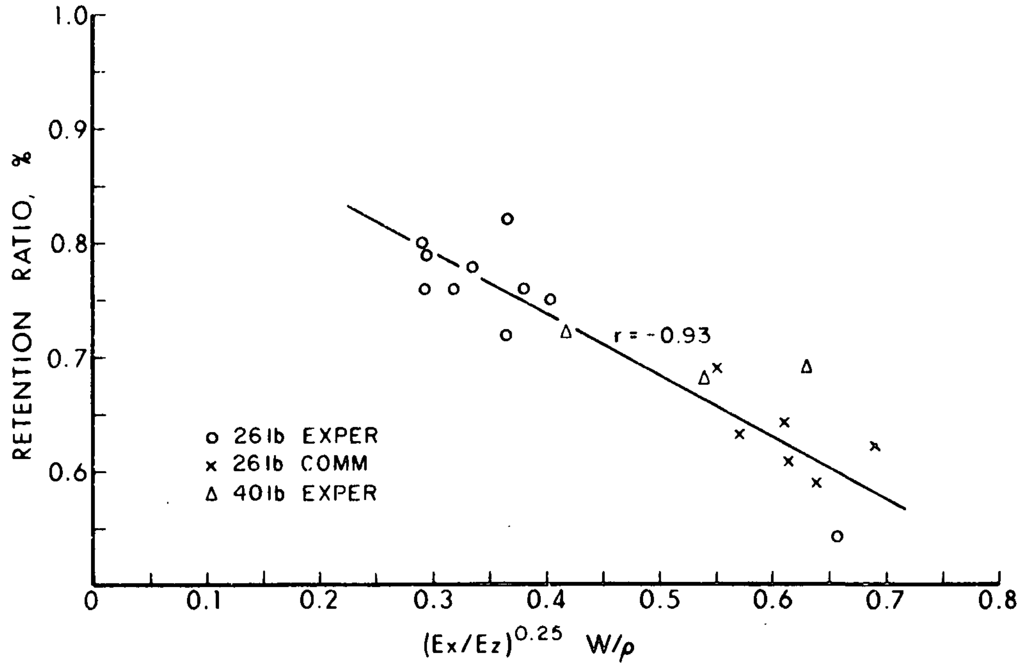


Figure 1. Strength retention during fluting depends on basis weight, density, and the elastic stiffness.

At constant basis weight, higher strength retention is favored by

1. Higher density achieved via better fiber-to-fiber bonding.
2. Lower MD stiffness (E_xt) and/or higher ZD stiffness (E_zt). Higher E_zt is related to better internal bonding, which helps the medium resist delamination type stress as it is bent to the fluted contour. Institute research has shown that higher strength retention can be achieved via higher wet pressing to improve fiber-to-fiber bonding. Higher wet pressing has two effects. First, it reduces thickness which reduces bending strains. Second, the densification tends to increase E_zt at a faster rate than E_xt, thus promoting forming with less fiber-to-fiber bond damage.

Because of its viscoelastic nature the elastic stiffnesses of the sheet will be affected by the moisture and temperature conditions in the preconditioners on the corrugator. Higher moistures and temperatures will decrease the stiffnesses, and hence "soften" the sheet. They will also increase stretch but will lower tensile strength. Thus, better forming tends to be favored by higher web temperatures and moisture content, at least within limits. For example, several authors suggest that the optimum web moisture content at the nip should fall in the range of 6-9% (2-5). The moldability of medium as measured by McKenzie and Yuritta (6) also suggests that the optimum web moisture should be in the 6-12% range. In general it appears that optimum benefit is attained when the moisture levels at the nip are achieved by use of preconditioner heat and steam on the corrugator (2,4).

The general effects of temperature and moisture on the in-plane properties of paper are well known. However, there is little information on the ZD properties such as E_zt. As discussed in later pages, there are indications that low moisture contents increase E_xt more than E_zt, which could have an adverse effect on formability.

Compressive strength increases as E, E_z, and G_z increase. In the cross direction these properties should be high to maintain or improve CD compressive strength. In the machine direction the moduli should also be high to achieve flat crush strength, but the losses may increase if G_{xz} becomes too high. Thus, end-use and fluting properties must be balanced to give the best overall performance.

RESULTS

To help evaluate what moisture and temperature conditions are needed to change the medium properties in the proper direction, special instrumentation was mounted on the corrugator after the showers (Fig. 2). This included an in-plane elastic property sensor, a Scanpro moisture meter, and an Ircon radiation thermometer. For this application the ultrasonic sensors were mounted in a hollow cylindrical roll rather than on individual wheels (Fig. 3). The sensor roll was located after the main shower. Three sensors (two transmitters, one receiver) were installed in the circumferential direction in the hollow roll to allow measurement of the MD elastic stiffness. The sensor outputs were digitized and analyzed with an APPLE computer.

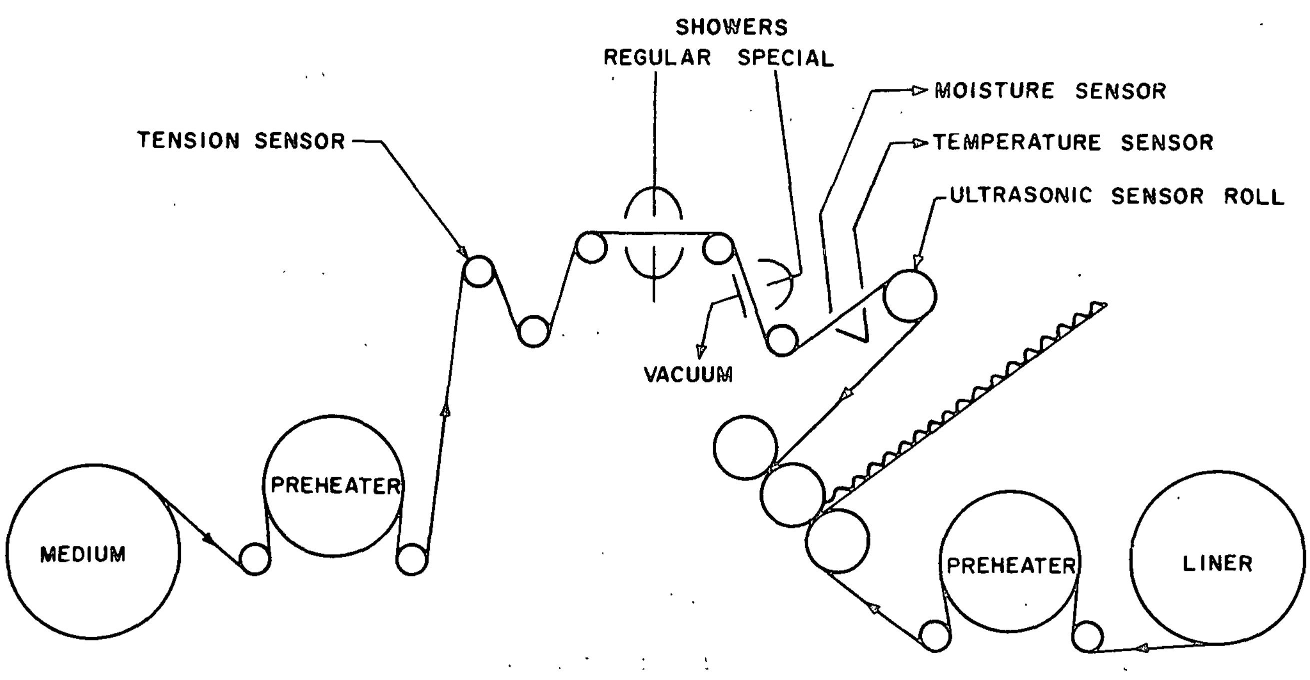


Figure 2. Schematic of single-facer with on-machine instrumentation for initial trials.

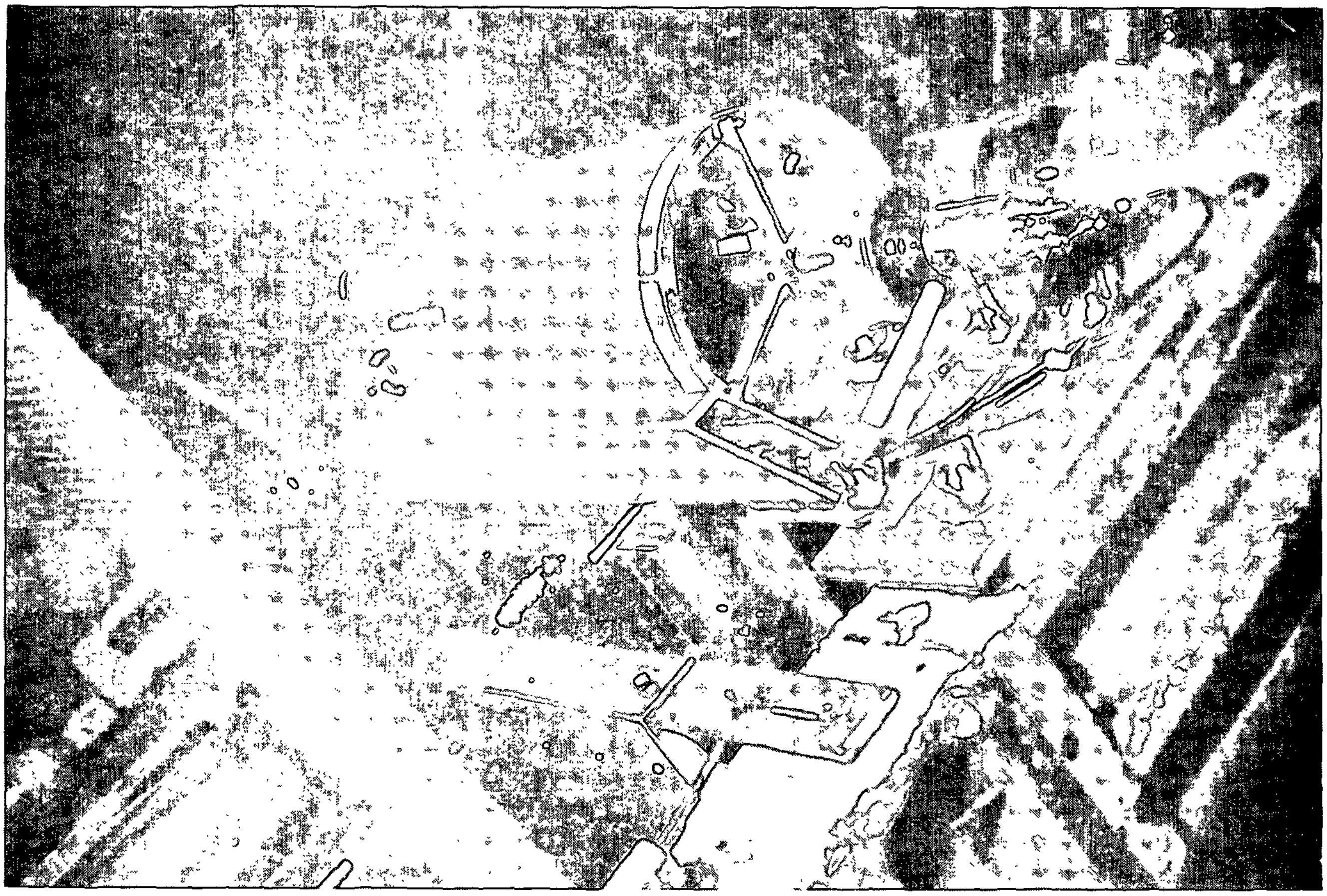


Figure 3. Ultrasonic elastic stiffness sensor mounted on single-facer after showers.

The in-plane stiffness and moisture meters measure average bulk properties of medium. However, the temperature measurement is probably more sensitive to surface condition. This should be kept in mind in examining the results.

CONVENTIONAL AND VACUUM SHOWER SYSTEMS

In our initial trials we mounted a vacuum type shower before our regular main shower (Fig. 2). The shower itself was loaned to us by the Lodding Co. We used it to steam one side of the sheet. Vacuum was applied to the other side in an effort to draw steam into the sheet.

Tables 1 and 2 summarize the on-machine operating data obtained during the corrugating trials on two nonsulfur type mediums. Table 3 shows similar results on a recycled fiber medium. Note that Runs 1 and 2 were made without the preheater but with and without showers. These runs helped determine the initial stiffness of the medium without any treatment, as well as the shower effect on a cold sheet. Runs 4-8 were made with the preheater on, with hot corrugating rolls, and with various shower conditions. We used both our regular two-sided shower and the special vacuum shower. The latter was mounted just after the regular shower and steamed one side of the sheet. Vacuum was applied to the other side in an effort to draw steam into and through the sheet. For initial trial purposes the web was dragged over the vacuum surface. This is not desirable because it increases the tension in the web.

Figures 4 and 5 illustrate the effects of preheat and steam on two 26-lb mediums at 600 fpm. Using the showers on a room temperature sheet greatly increased the moisture because of greater condensation within the sheet. In general this was the only condition where the moisture contents after the showers were greatly above the base moisture content, reaching about 9-10% for these mediums. The surface temperatures reached about 150° F at 600 fpm and were somewhat lower than attained at 200 fpm, as expected. Associated with the moisture and temperature increases were decreases in the MD stiffness of about 10-15% which would be expected to enhance formability.

With the preheater on and a hot machine with showers, surface temperatures approached or exceeded 200°F on the 26-lb mediums, depending somewhat on the shower condition used (Fig. 4 and 5). Under these shower conditions the moisture contents appeared to remain about constant at about the base sheet

Table 1. On-machine moisture, temperature, and stiffness data.

MILL A SEMICHEMICAL

Run	Corr. Roll Temp.	Preheat	Shower	Speed, fpm	26-lb, Roll 6169 Temp., °F	26-lb, Roll 6169 H_2O, %	26-lb, Roll 6169 E_x/ρ, MNm/kg	26-lb, Roll 6169 % Diff.[a]	33-lb, Roll 6168 Temp., °F	33-lb, Roll 6168 H_2O, %	33-lb, Roll 6168 E_x/ρ, MNm/kg	33-lb, Roll 6168 % Diff.[a]	40-lb, Roll 6170 Temp., °F	40-lb, Roll 6170 H_2O, %	40-lb, Roll 6170 E_x/ρ, MNm/kg	40-lb, Roll 6170 % Diff.[a]
1	Hot	None	None	50	100-	6.4	8.32	--	100-	6.7	7.76	--	100-	6.2	8.54	--
				200	100-	6.4	8.09	--	100-	6.7	7.93	--	100-	6.1	8.44	--
				600	100-	6.4	8.15	--	100-	6.7	8.88	--	100-	6.1	8.45	--
2	Hot	None	Reg.	50	125	13.0	5.89	-29	130	12.0	5.84	-29	130	10.5	5.58	-34
				200	160	10.0	5.81	-30	160	9.5	5.88	-28	160	8.5	6.14	-28
				600	155	9.5	7.08	-15	145	8.5	6.53	-20	140	7.5	7.08	-17
4	Hot	Full	None	50	160	3.5	9.11	+9	150	3.5	8.21	0	110	4.0	8.65	-2
				200	150	5.5	8.04	-3	140	5.0	7.26	-11	115	5.5	8.14	-4
				600	125	7.0	7.67	-8	115	6.5	7.67	-6	100-	6.5	7.98	-6
5	Hot	Full	Reg.	50	190	5.5	7.98	-4	180	4.0	7.22	-12	165	5.5	6.84	-19
				200	195	5.0	7.36	-12	190	5.0	6.69	-18	175	6.5	6.91	-19
				600	185	6.5	7.41	-11	175	6.5	6.81	-17	155	7.0	7.12	-16
6	Hot	Full	Spec.	50	210	4.0	8.53	+3	210	4.0	7.19	-12	205	4.5	7.14	-16
				200	210	5.0	8.14	-2	210	5.5	6.36	-22	210	7.0	6.68	-21
				600	210	7.0	6.44	-23	185	7.0	6.14	-25	170	7.5	6.37	-25
7	Hot	Full	Spec., no vac.	50	210	3.5	8.21	-1	--	--	--	--	--	--	--	--
				200	205	4.5	7.77	-7	--	--	--	--	--	--	--	--
				600	175	6.0	7.52	-10	--	--	--	--	--	--	--	--
8	Hot	Full	Reg./spec.	50	205	4.0	7.87	-5	--	--	--	--	--	--	--	--
				200	210	4.5	7.51	-10	--	--	--	--	--	--	--	--
				600	210	6.0	6.77	-19	--	--	--	--	--	--	--	--

[a]Based on Run 1 results.

Table 2. On-machine moisture, temperature, and stiffness data.

MILL C SEMICHEMICAL

Run	Corr. Roll Temp.	Preheat	Shower	Speed, fpm	26-lb, Roll 6153/4 Temp., °F	26-lb, Roll 6153/4 H_2O, %	26-lb, Roll 6153/4 E_x/ρ, MNm/kg	26-lb, Roll 6153/4 % Diff.[a]	40-lb, Roll 6157 Temp., °F	40-lb, Roll 6157 H_2O, %	40-lb, Roll 6157 E_x/ρ, MNm/kg	40-lb, Roll 6157 % Diff.[a]
1	Hot	None	None	50	100-	6.0	--	--	100-	5.6	--	--
				200	100-	6.0	8.92	--	100-	5.6	8.32	--
				600	100-	6.0	9.14	--	100-	5.6	--	--
2	Hot	None	Reg.	50	--	--	--	--	125	11.0	--	--
				200	140	8.0	7.32	-19	145	7.0	6.48	-22
				600	145	7.5	7.77	-6	125	6.0	6.52	-22
4	Hot	Full	None	50	105	3.0	10.16	+14	115	4.0	--	--
				200	120	4.0	9.16	+1	110	5.0	8.20	-1
				600	105	5.5	9.22	+1	100-	5.0	8.39	+1
5	Hot	Full	Reg.	50	150	3.5	9.34	+5	145	3.0	--	--
				200	170	4.0	8.11	-10	150	5.0	7.31	-12
				600	165	5.5	8.10	-10	135	5.5	7.36	-12
6	Hot	Full	Spec.	50	185	4.0	8.1[b]	-10	150	5.0	--	--
				200	190	6.0	7.3[b]	-19	160	6.5	6.56	-21
				600	190	8.5	6.3[b]	-30	125	7.0	7.46	-10

[a]Based on Run 1 results.

level or decrease slightly at 600 fpm (Fig. 4 and 5). At very low speeds, use of the preheater only elevated the temperature and decreased moisture markedly, and hence tended to increase the stiffness of medium. Generally, the greatest reductions in stiffness at high speed were achieved with either the special shower or the combination of regular and special showers.

Table 3. On-machine moisture, temperature, and stiffness data.

MILL B RECYCLED

Run	Corr. Roll Temp.	Preheat	Shower	Speed, fpm	26-lb, Roll 6145 Temp., °F	H_2O, %	E_x/ρ MNm/kg	% Diff.[a]
1	Hot	None	None	50	100	6.5	8.92	--
				200	100	6.0	9.34	--
				600	100-	6.5	9.27	--
2	Hot	None	Reg.	50	105	13.0	5.64	--
				200	140	11.5	7.56	-18
				600	135	10.0	7.67	-16
4	Hot	Full	None	50	175	3.0	9.97	+9
				200	165	4.5	9.27	+1
				600	145	6.0	8.81	-4
5	Hot	Full	Reg.	50	170	5.5	8.07	-12
				200	185	6.0	8.09	-12
				600	185	7.0	7.75	-16
6	Hot	Full	Spec.	50	200	5.0	8.55	-7
				200	210	6.5	8.04	-7
				600	195	6.5	8.04	-11
7	Hot	Full	Spec., no vac.	50	250	4.5	8.83	-4
				200	205	5.0	9.22	0
				600	180	6.0	9.54	+2
8	Hot	Full	Reg./spec.	50	200	4.5	8.61	-6
				200	210	5.5	8.45	-8
				600	210	6.5	6.99	-24

[a]Based on Run 1 results.

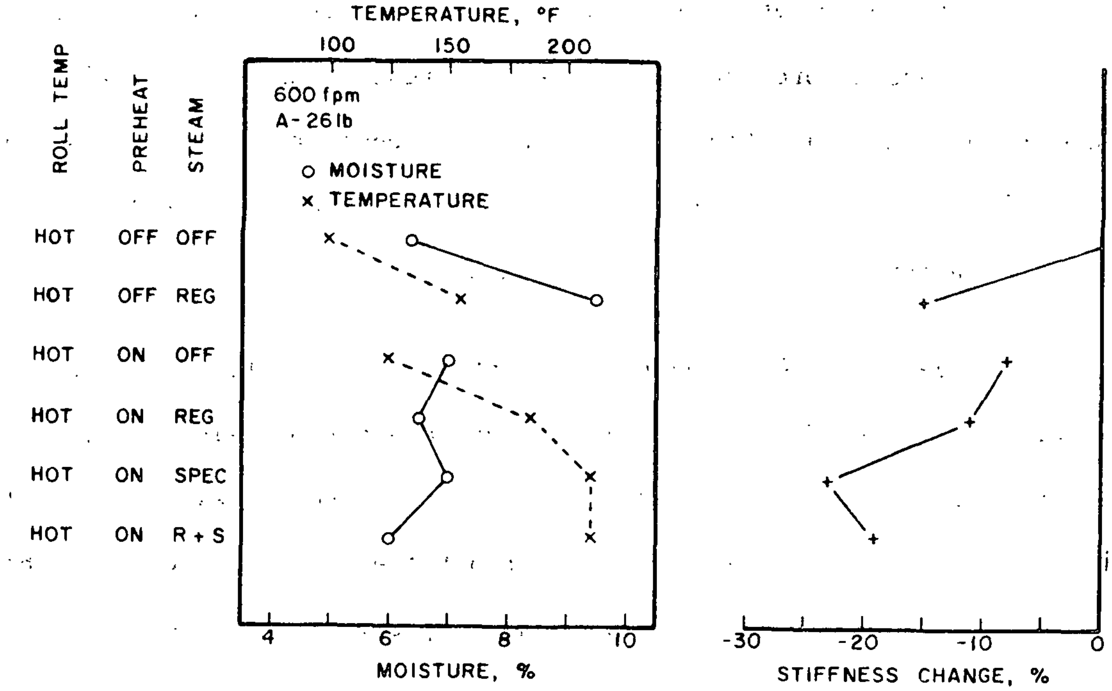


Figure 4. Effect of preheat and steam on medium temperature, moisture, and stiffness for a 26-lb semichemical medium.

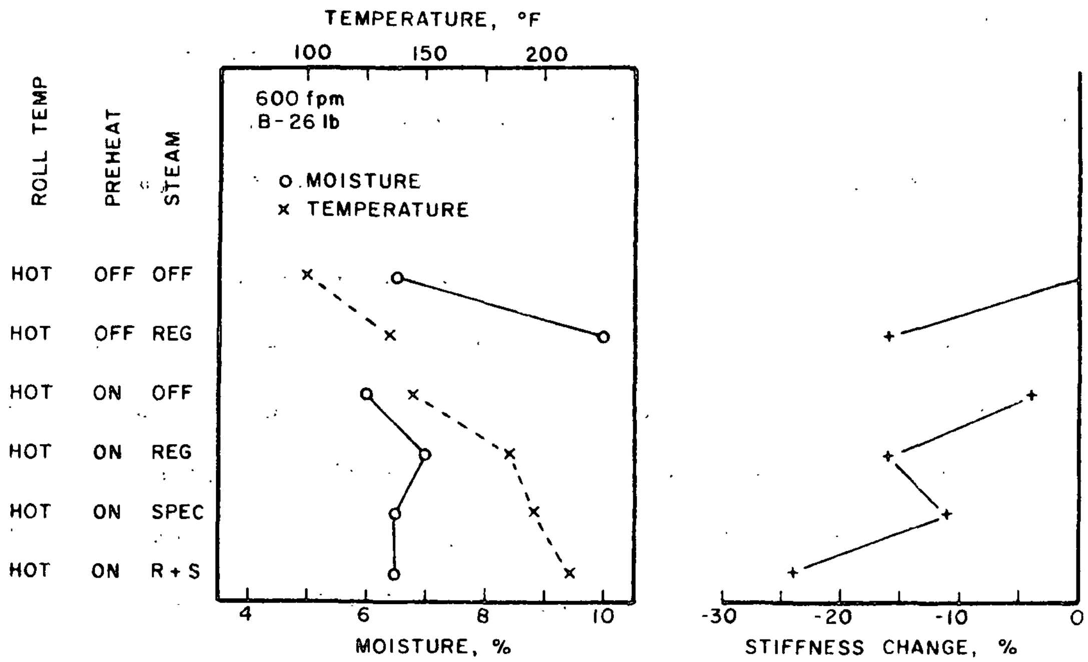


Figure 5. Effect of preconditioner conditions for a 26-lb recycled fiber medium.

For the heavier weight medium, lower temperatures were attained and the temperature decreased more rapidly as speed increased than for the 26-lb mediums (See Tables 1 and 2). However, the moisture contents tended to remain in the 5 to 7.5% range. The run combinations with higher moisture and temperature gave the greater reductions in stiffness.

At the speeds of 200 and 600 fpm, moisture contents tend to increase as the surface temperature decreases. These changes exert opposing effects on stiffness because it is affected by both moisture and temperature. As a result, the stiffness may increase, decrease, or stay about the same, depending on the extent of the moisture temperature changes and the particular medium.

The relative effects of moisture and temperature on stiffness were estimated by fitting parallel lines to the data for each medium as illustrated in Fig. 6 for one of the 26-lb mediums. Although there is considerable scatter, the regression lines indicate that increases in moisture and temperature decrease stiffness as expected. These effects of heat and steam on formability would be expected to depend on the balance attained by preconditioning.

Table 4 and Fig. 7 compare the moisture and temperature sensitivities of various mediums with regard to their effect on MD stiffness. Sensitivity is based on the magnitude of the regression coefficients relating E_x/ρ to moisture and temperature as measured on the corrugator. For example, the moisture and temperature regression coefficients correspond to the slopes and separation of the lines in Fig. 5. High coefficients indicate the elastic stiffness will be more affected by changes in the moisture and/or temperature conditions.

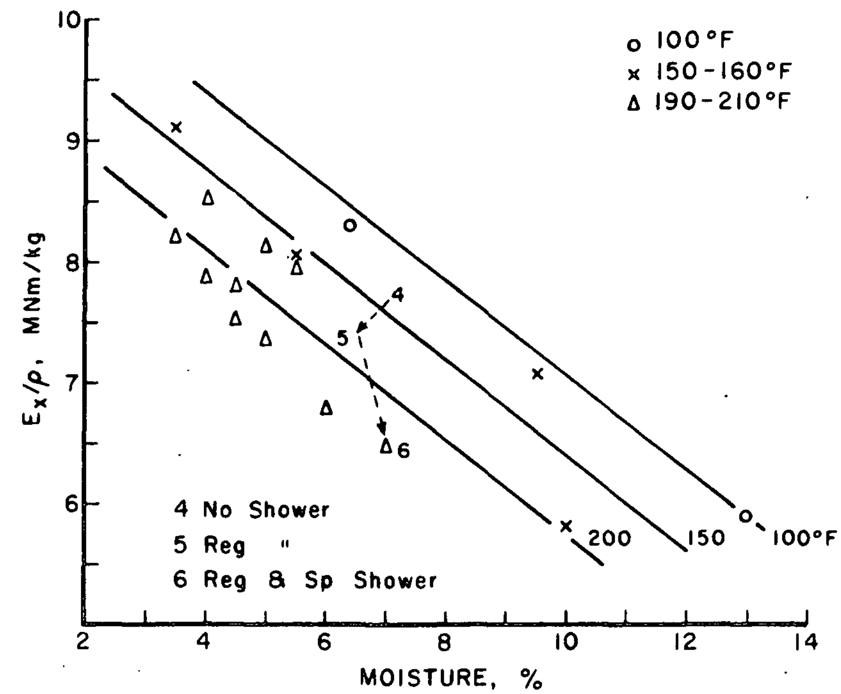


Figure 6. Relationship between moisture, surface temperature and E_x/ρ for a 26-lb semichemical medium.

Table 4. Sensitivity of E_x/ρ to moisture and surface temperature after showers.

Roll No.	Grade	Mfg. Code	Moisture (M) Coeff., a_1	Temp. (T) Coeff., a_2	Constant a_0	R^2
6169	26	A (SC)	-0.388	-0.0131	12.26	0.84
6168	33	A (SC)	-0.302	-0.0155	11.32	0.93
6170	40	A (SC)	-0.410	-0.0144	12.04	0.90
6145	26	B (REC.)	-0.407	-0.0102	12.73	0.72
6153	26	C (SC)	-0.382	-0.0198	13.33	0.94
6157	40	C (SC)	-0.344	-0.0237	12.44	0.78
Av.			-0.372	-0.0161		

Note: $E_x/\rho = a_0 + a_1M + a_2T$.
SC = Semichemical; REC. = Recycled.

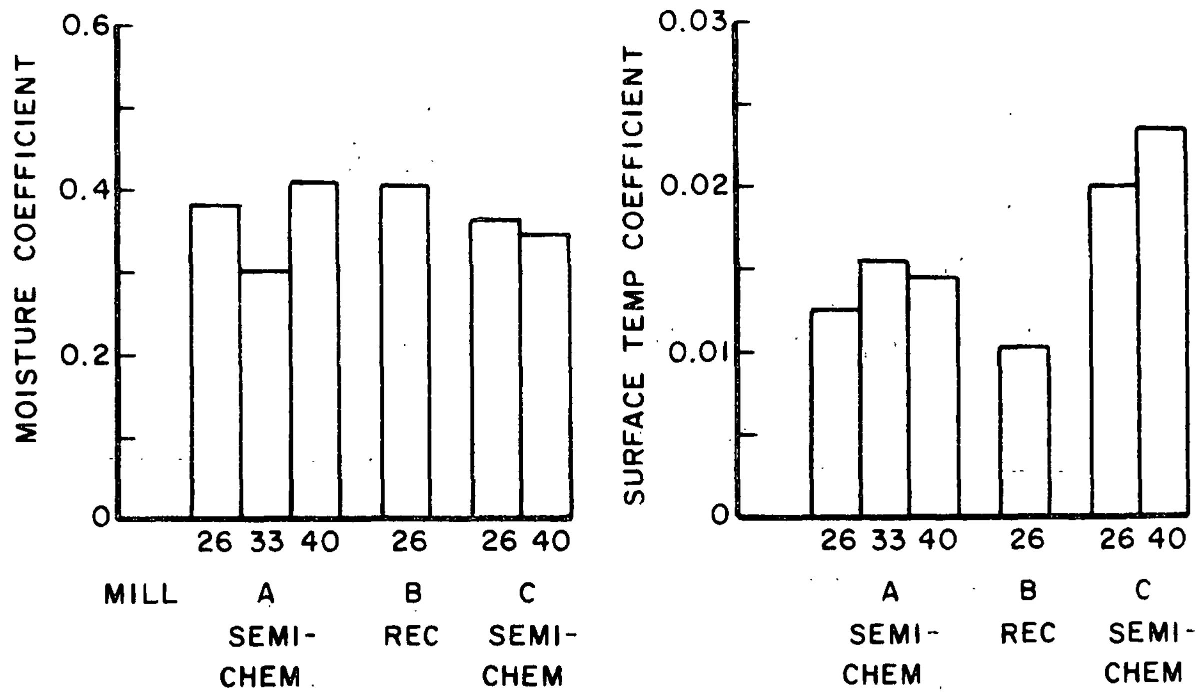


Figure 7. Comparison of moisture and surface temperature factor affecting stiffness, E_x/ρ.

On the average an increase in moisture of 1% decreases stiffness by about 4-7% and a 25°F increase in temperature produces a similar effect on stiffness. In general, the mediums exhibited about the same stiffness/moisture sensitivity. However, the mediums from the three sources appeared to exhibit different stiffness/temperature sensitivities. The recycled medium exhibited the lowest sensitivity, indicating that greater temperature changes are required to affect stiffness. In contrast, some of the semichemical mediums appeared to be about twice as sensitive to temperature changes as the recycled medium (See Fig. 8). The semichemical mediums from the two sources also appeared to exhibit differences in temperature. In general, the Mill C semichemical medium tended to exhibit greater stiffness decreases for a given increase in temperature than the Mill A semichemical mediums.

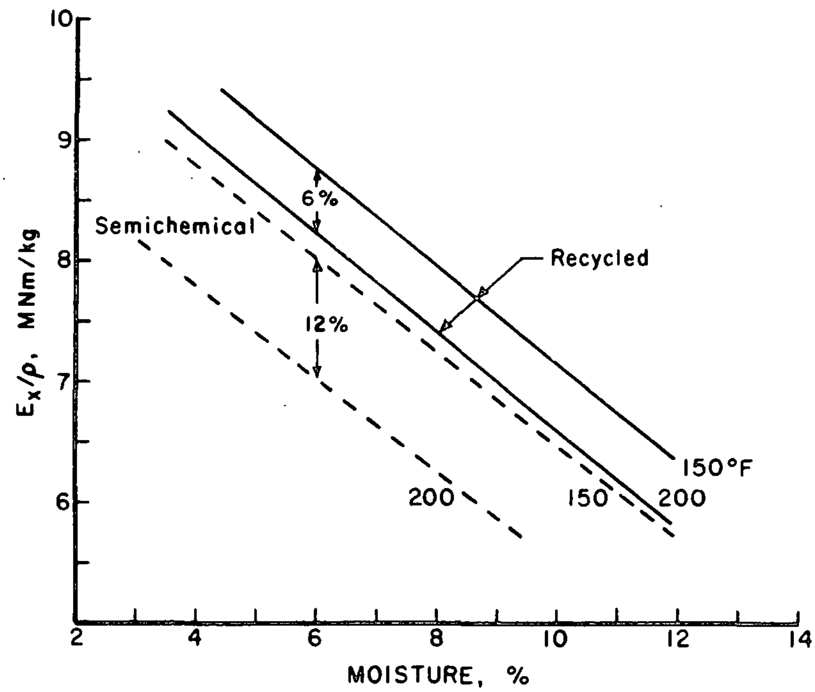


Figure 8. Comparison of moisture and temperature sensitivities of 26-lb semichemical (C) and recycled fiber-medium (B).

A number of furnish and papermaking factors might affect the differing responses of the above mediums to preconditioning. On a speculative basis, the recycled fiber medium should have lower hemicelluloses and lignins than the semichemical mediums. Thus, greater temperature changes might be required to affect stiffness. However, this particular recycled fiber medium also exhibited lower porosity and water drop (receptivity) than the semichemical mediums (see Table 5). Both properties could affect temperature (and moisture) pick-up in the preconditioning process.

The flat crush results tended to increase as the stiffnesses decreased (Fig. 9). The stiffness decreases as higher web moistures are attained and also with higher temperatures. The flat crush increases occur because the medium is fluted with less damage when the stiffness is lowered by higher moistures and temperatures. However, the increases obtained were modest, ranging around 10-15%.

Table 5. Physical characteristics of mediums.

Property	Mill A - Semichemical 26-lb (6169)	33-lb (6168)	40-lb (6170)	Mill B - Recycled 26-lb (6145)	Mill C - Semichem. 26-lb (6153/4)	40-lb (6157)
Basis weight, lb/m ft^2	25.6	32.1	38.7	26.2	25.6	40.0
Caliper (TAPPI), mil	10.4	12.9	15.0	9.6	11.4	15.9
Density, lb/ream - mil	2.46	2.49	2.58	2.73	2.25	2.52
STFI comp., kN/m MD	3.41	4.30	5.27	3.35	3.60	5.56
CD	2.09	2.71	3.30	1.91	2.08	3.41
Concora, lb	53.6	77.7	87.0	63.2	56.8	87.2
Bendtsen porosity, mL/min	961	872	686	519	1220	720
Water drop, s						
Felt side	114	58	138	425	266	187
Wire side	107	44	123	374	262	183
Av.	110	51	130	399	264	185

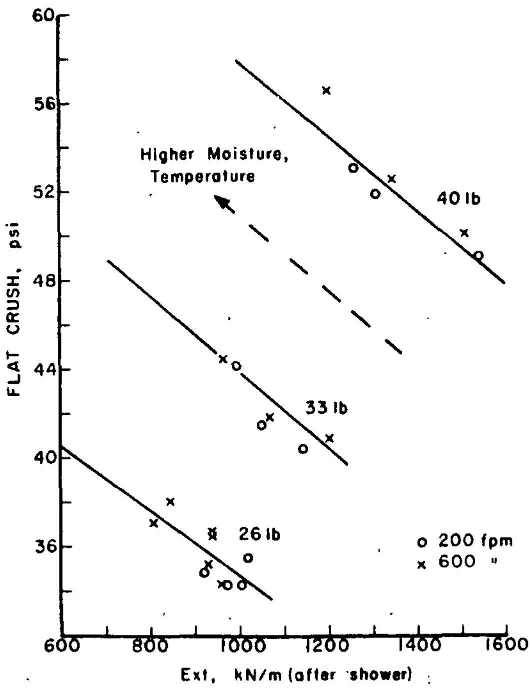


Figure 9. Higher medium moisture contents and temperatures after showers decrease medium stiffness and increase flat crush.

The vacuum shower as used here caused runnability problems. If the vacuum level was too high, the resulting increased tension in the medium web caused fracture. Even low levels of vacuum caused increased high-lows because of the higher web tension (see Table 6). It is clear that any vacuum shower arrangement would require a rotating sectored vacuum roll to prevent increases in medium web tension and hence high-lows.

Table 6. High-low results for regular and vacuum shower operation.

Shower Condition	Percent high-lows greater than indicated value[a].			
	3.0 mil		4.0 mil	
	Rec.	Semichem.	Rec.	Semichem.
Off	1.6	17.6	0.9	6.8
Regular main shower	7.4	8.0	2.4	3.2
Vacuum shower	28.0	28.3	10.8	14.6
Reg. and vacuum	30.6	37.6	18.2	25.4

[a]On 600 fpm single-faced boards.

While a rotating vacuum roll is technically possible, it would be costly for the benefits attained. Therefore, it was decided to add an extra conventional shower of the Gaylord type for subsequent work.

EXTRA SHOWER AND OPERATIONAL IMPROVEMENTS

As a result of these experiences we made modifications to the pilot corrugator. These modifications were directed to making steam shower improvements, reducing moisture and temperature losses from the medium web and improving the operation of the same stiffness sensor.

Figure 10 schematically shows the location of the showers and sensors after modification. The changes made are described below.

1. A Gaylord type shower was designed and installed on the machine just before the present shower. This necessitated moving the present shower forward from its previous location. The Gaylord shower replaces the vacuum shower which was used in previous work.

2. A Lodding shower was mounted after the preheater and before the Gaylord shower.

3. An insulated duct was installed to help retain the moisture and temperature in the medium web after the Lodding shower. This is desirable because of the long path of the medium between the Lodding and Gaylord showers.

4. The ultrasonic sensor roll was relocated to reduce the path length of the medium web between the top shower and corrugating labyrinth.

5. The moisture sensor was relocated to a position immediately before the corrugating labyrinth. This sensor was previously located before the ultrasonic sensor and was several feet from the labyrinth.

6. The transducer locations in the sensor roll were modified to bring the sender and receivers closer together. This change provided more stable and reliable readings of stiffness under rapidly changing corrugator conditions.

7. Insulated guards were installed around the ultrasonic sensor roll to reduce heat buildup.

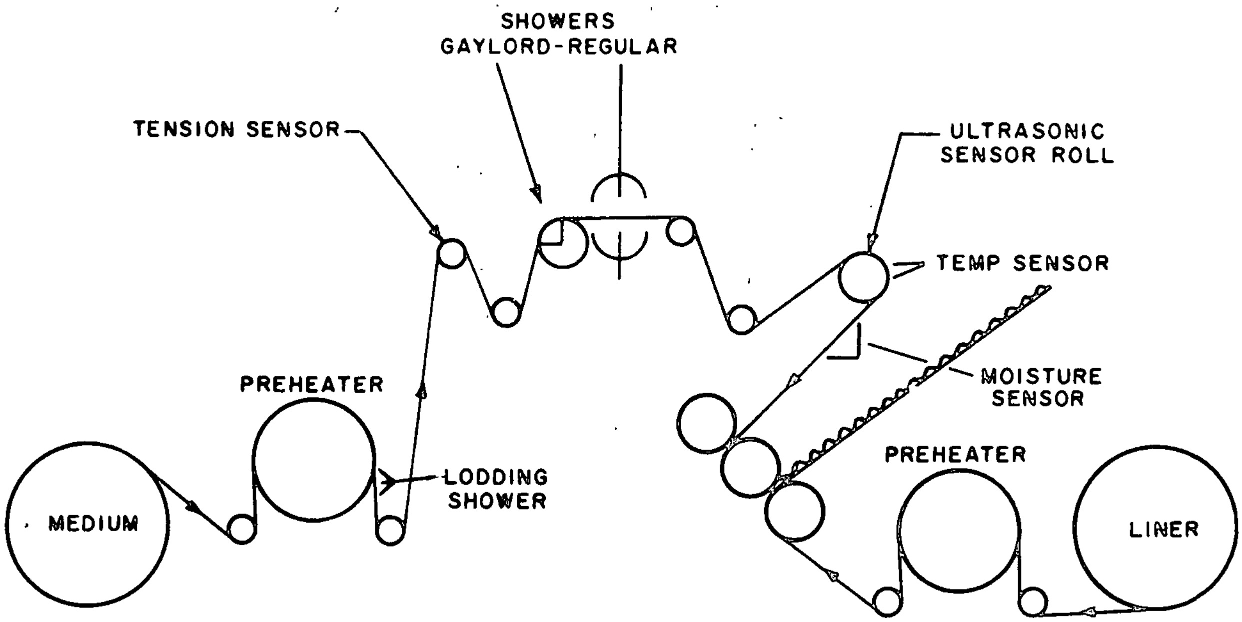


Figure 10. Schematic of single-facer with modified shower and instrumentation system.

STEAM SHOWER AND PREHEAT TRIALS

Initial trials were carried out with various combinations of preheat and steam showers using a 26-lb northern semichemical medium. For these trials we measured medium web temperatures and moistures after the showers. The single-faced boards were evaluated for flat crush and single-faced ring compressive strength (a test related to combined board ECT). Stiffness measurements were not carried out due to an equipment breakdown.

The results in Table 7 indicate that the use of the showers increases the medium moisture content before the nip by about 2 to 2.5% relative to the preheater alone. The higher moisture contents appeared to increase flat crush by small amounts and had little effect on single-face ring. In these trials there were only small differences, if any, in web moisture between the runs with one and both showers (Runs 2-5). Running with no preheat wrap (Run 5) gave no

Table 7. Corrugating trials with various shower/preheater combinations.

		Run 1	Diff. %	Run 2	Diff. %	Run 3	Diff. %	Run 4	Diff. %	Run 5	Diff. %
Preheat wrap		full		full		1/2		1/2		none	
Showers, main		off		on		on		on		on	
Gaylord		off		off		off		on		on	
Moisture, %	50 fpm	2.5	--	5.0	--	6.0	--	6.5	--	6.5	--
	400 fpm	6.0	--	8.0	--	8.0	--	8.5	--	9.0	--
	600 fpm	6.0	--	9.0	--	9.0	--	9.0	--	9.5	--
Temp., °F =	50 fpm	190	--	150	--	130	--	135	--	135	--
	400 fpm	135	--	155	--	150	--	155	--	155	--
	600 fpm	120	--	145	--	160	--	155	--	150	--
Flat crush, psi	400 fpm	28.8	--	31.1	+8.0	31.8	+10.4	32.4	+12.5	31.4	+9.0
	600 fpm	29.1	--	31.3	+7.6	32.0	+10.0	33.3	+14.4	32.4	+11.3
S.F. ring, lb/inch	400 fpm	27.9		27.0	-3.2	26.1	-6.5	26.6	-4.6	26.3	-6.1
	600 fpm	26.5		26.4	-0.4	25.8	-2.6	26.2	-1.1	25.5	-3.8

Note: 26-lb northern semichemical mediums.

benefits in terms of board performance. In other trials the Lodding shower appeared to have little effect.

In view of the above, subsequent trials were carried out using only three conditions. They were

1. Full preheat wrap, no showers,
2. Full preheat wrap, main shower,
3. One-half preheat wrap, main and Gaylord shower.

The results are summarized in Tables 8-11 for the two 26-lb, the 33-lb, and the 40-lb semichemical mediums, respectively. Except in two instances the 26- and 33-lb mediums did not fracture at 600 fpm and high tensions. The 40-lb medium with low moisture (preheater only) fractured at 600 fpm and minimum tension (0.5 lb/inch). At the higher moistures attained with the showers, the medium ran without visible fractures at 600 fpm and minimum tension. However, fractures occurred when the tension level was raised 1.5 lb/inch.

Figures 11-14 compare the properties of the medium after the showers at 600 fpm. In all cases, using both steam showers gave the highest moisture contents and lowest MD medium stiffnesses. Higher web temperatures were also attained with both showers. The higher moistures and temperatures achieved with the showers lower the stiffness of the medium, and hence should promote forming.

Figure 15 shows that medium stiffness decreases significantly as the moisture is increased, neglecting temperature effects. Thus, the use of showers which maintain or increase moisture content is beneficial.

Table 8. Shower/preheater trials on 26-lb semichemical medium (Roll 6295).

Preheat wrap Showers, main Gaylord	Speed, fpm	Web Tension, lb/inch	Full Off Off	Full On Off	1/2 On On
Moisture, %	50	0.5	2.5	4.0	7.5
	400	0.5	5.5	8.5	11.0
	600	0.5	6.0	9.5	11.5
	600	1.5	6.0	8.5	10.5
	600	2.5	5.5	8.5	10.5
Medium temp.,°F	50	0.5	143	147	136
	400	0.5	125	157	157
	600	0.5	<100	143	127
	600	1.5	100	152	136
	600	2.5	100	152	143
Ex/ρ, MNm/kg	50	0.5	7.09	6.96	6.25
	400	0.5	5.97	5.39	4.80
	600	0.5	6.25	5.23	4.65
	600	1.5	7.86	6.08	5.32
	600	2.5	--	6.43[b]	5.53
Flat crush, psi	400	0.5	29.1	31.8 (+9.2)[a]	31.4 (+7.9)[a]
	600	0.5	28.8	30.8 (+6.2)[a]	32.3 (+12.2)[a]
S.F. ring crush, lb/inch	400	0.5	27.4	27.7 (+ 1.1)	27.7 (+ 1.1)
	600	0.5	26.0	26.6 (+ 2.3)	26.8 (+ 3.1)
	Diff.%		-5.1	-4.0	-3.2

[a]Figure in parentheses is the percentage change in flat crush and S.F. ring crush based on the no-shower condition.
[b]Flute fracture.

Table 9. Shower/preheater trials on 26-lb semichemical medium (Roll 6297).

Preheat wrap Showers, main Gaylord	Speed, fpm	Web Tension, lb/inch	Full Off Off	Full On Off	1/2 On On
Moisture, %	50	0.5	3.0	3.5	5.5
	400	0.5	6.0	8.5	10.5
	600	0.5	7.0	9.5	11.5
	600	1.5	7.0	8.5	10.5
	600	2.5	7.5	8.5	10.0
Medium Temp., °F	50	0.5	153	157	144
	400	0.5	133	168	165
	600	0.5	117	162	165
	600	1.5	118	165	168
	600	2.5	125	167	168
E_x/ρ, MNm/kg	50	0.5	8.56	8.47	7.09
	400	0.5	7.24	6.81	5.92
	600	0.5	6.81	6.49	5.60
	600	1.5	9.59	8.02	7.46
	600	2.5	0.67	8.57	7.94
Flat crush, psi	400	0.5	32.2	35.6 (+10.6)[a]	35.1 (+9.0)[a]
	600	0.5	32.2	37.0 (+14.9)[a]	35.6 (+10.6)[a]
S.F. Crush, lb/inch	400	0.5	26.7	27.3 (+2.2)	27.0 (+1.1)
	600	0.5	26.0	26.3 (+1.2)	26.4 (+1.5)
	Diff.%		-2.6	-3.7	-2.2

[a]Figure in parentheses is the percentage change in flat crush and S.F. ring crush based on no-shower condition.

Table 10. Shower/preheater trials on 33-lb semichemical medium (Roll 6298).

Preheat wrap Showers, main Gaylord	Speed, fpm	Web Tension, lb/inch	Full Off Off	Full On Off	1/2 On On
Moisture, %	50	0.5	2.0	3.0	5.5
	400	0.5	4.0	7.0	10.5
	600	0.5	4.0	8.0	11.0
	600	1.5	5.0	7.5	11.0
	600	2.5	5.0	7.5	10.5
Medium temp., °F	50	0.5	157	162	142
	400	0.5	130	172	167
	600	0.5	<100	143	160
	600	1.5	100	157	160
	600	2.5	100	160	162
E_x/ρ, MNm/kg	50	0.5	7.95	7.85	6.74
	400	0.5	7.16	5.88	5.32
	600	0.5	7.16	6.03	5.32
	600	1.5	8.27	7.12	5.96
	600	2.5	8.75[b]	7.61	6.31
Flat crush, psi	400	0.5	32.2	38.9 (+20.8)[a]	38.3 (+18.9)[a]
	600	0.5	32.8	39.6 (+20.7)[a]	40.1 (+22.2)[a]
S.F. ring crush, lb/inch	400	0.5	30.2	31.8 (+5.3)	31.1 (+3.6)
	600	0.5	27.2	30.4 (+11.8)	30.6 (+12.5)
	Diff.%		-9.9	-4.4	-2.2

[a]Figure in parentheses is the percentage change in flat crush and S.F. ring crush based on no-shower condition.
[b]Flute fracture.

Table 11. Shower/preheater trials on 40-lb semichemical medium (Roll 6294).

Preheat wrap Showers, main Gaylord	Speed, fpm	Web Tension, lb/inch	Full Off Off	Full On Off	1/2 On On
Moisture, %	50	0.5	3.0	4.5	7.5
	200	0.5	5.0	10.0	9.5
	600	0.5	6.0	10.0	12.0
	600	1.5	5.5	9.5	12.5
	600	2.5	5.0	9.5	12.5
Medium temp., °F	50	0.5	152	160	143
	200	0.5	130	167	162
	600	0.5	<100	142	105
	600	1.5	<100	142	125
	600	2.5	<100	142	147
Ex/ρ, MNm/kg	50	0.5	5.51	5.31	4.46
	200	0.5	5.05	4.33	3.83
	600	0.5	5.32[b]	4.46	3.59
	600	1.5	6.43[b]	4.84[b]	3.76[b]
	600	2.5	6.43[b]	4.80[b]	3.98[b]
Flat crush, psi	200	0.5	41.1	42.6 (+3.6)[a]	42.4 (+3.2)[a]
	600	0.5	--[b]	43.6	43.2
S.F. ring crush, lb/inch	400	0.5	34.9	36.1 (+3.4)	36.2 (+3.7)
	600	0.5	--	32.3 --	33.0 --
	Diff.%			-10.5	-8.8

[a]Figure in parentheses is the percentage change in flat crush and S.F. ring crush based on no-shower condition.
[b]Flute fracture.

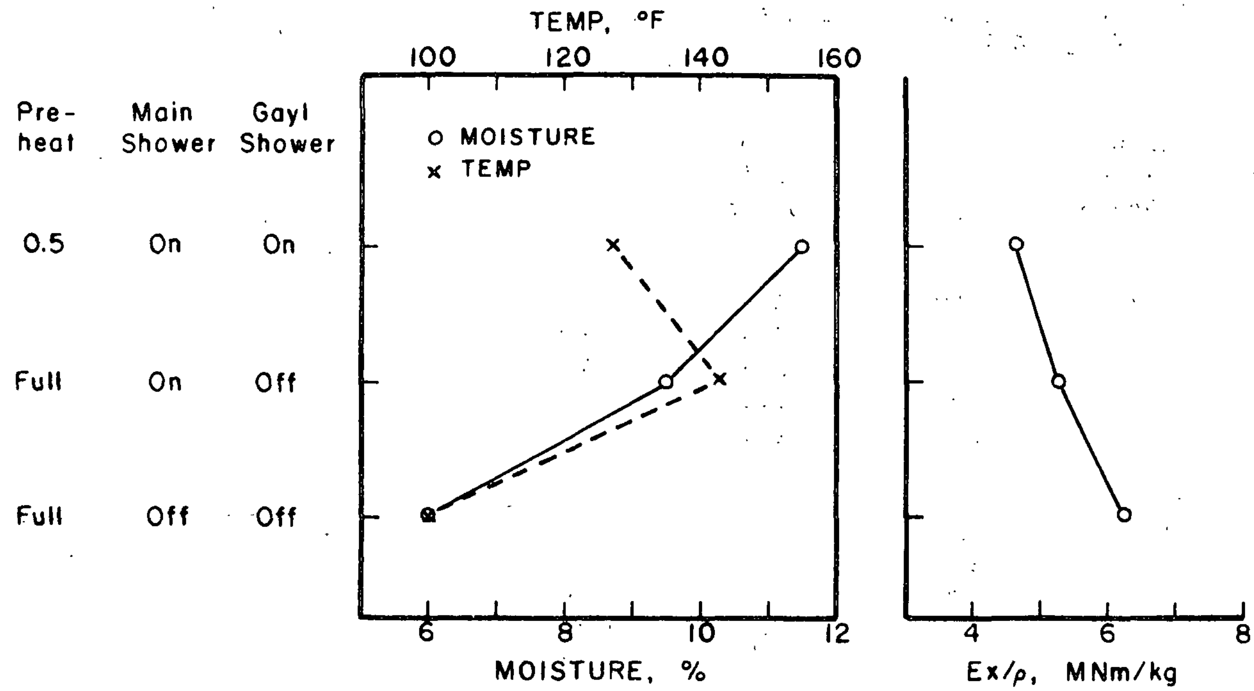


Figure 11. Effect of preheat and steam shower conditions on medium moisture, temperature, and stiffness at 600 fpm (26-lb semichemical medium, Roll 6295).

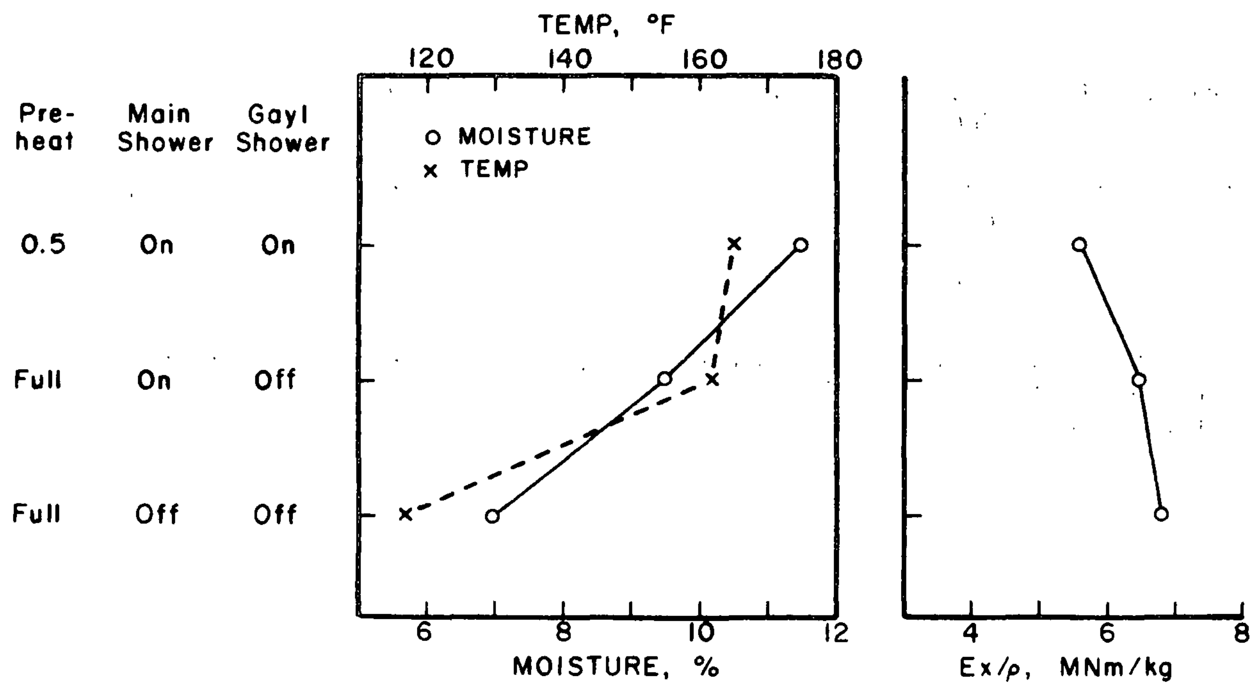


Figure 12. Effect of preheat and steam shower conditions on medium moisture, temperature, and stiffness at 600 fpm (26-lb semichemical medium, Roll 6297).

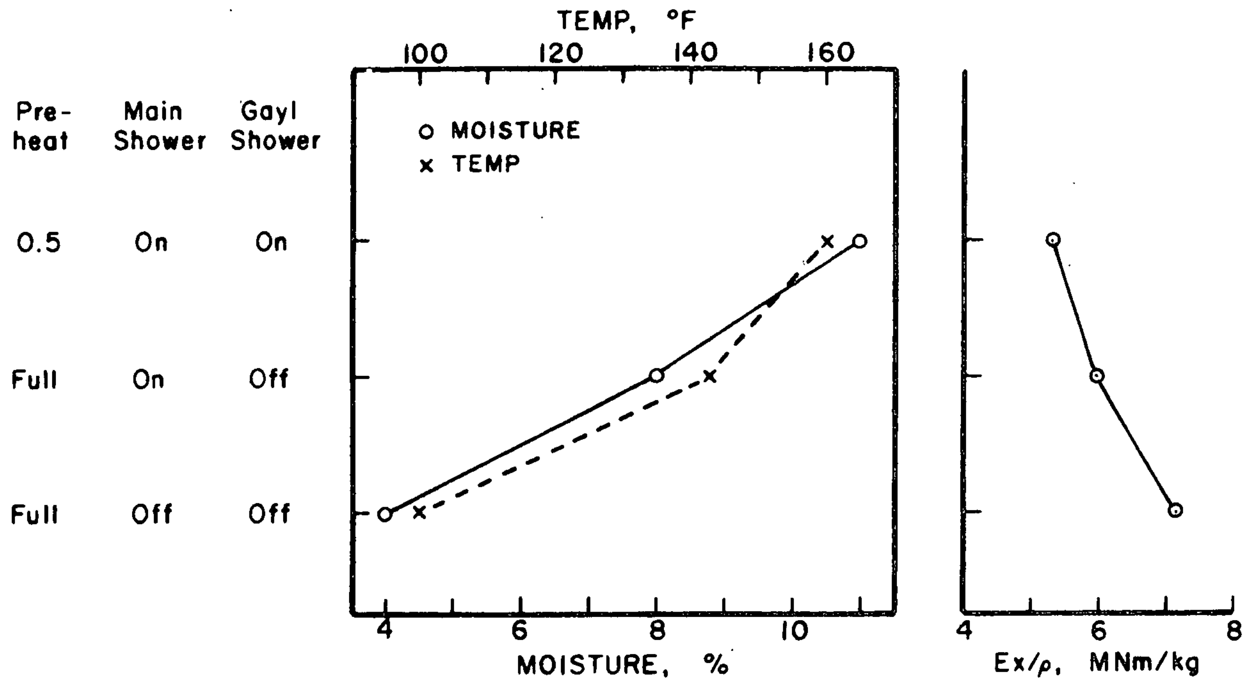


Figure 13. Effect of preheat and steam shower conditions on medium moisture, temperature, and stiffness at 600 fpm (33-lb semichemical, Roll 6298).

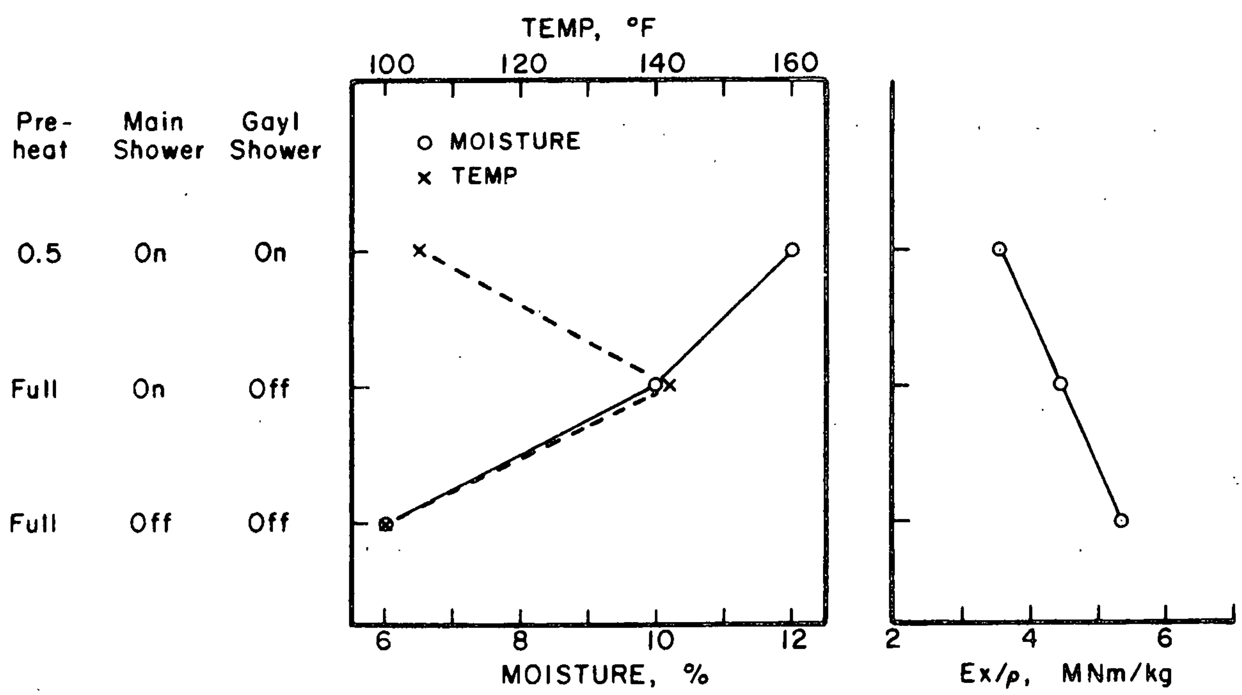


Figure 14. Effect of preheat and steam shower conditions on medium moisture, temperature, and stiffness at 600 fpm (40-lb semichemical, Roll 6294).

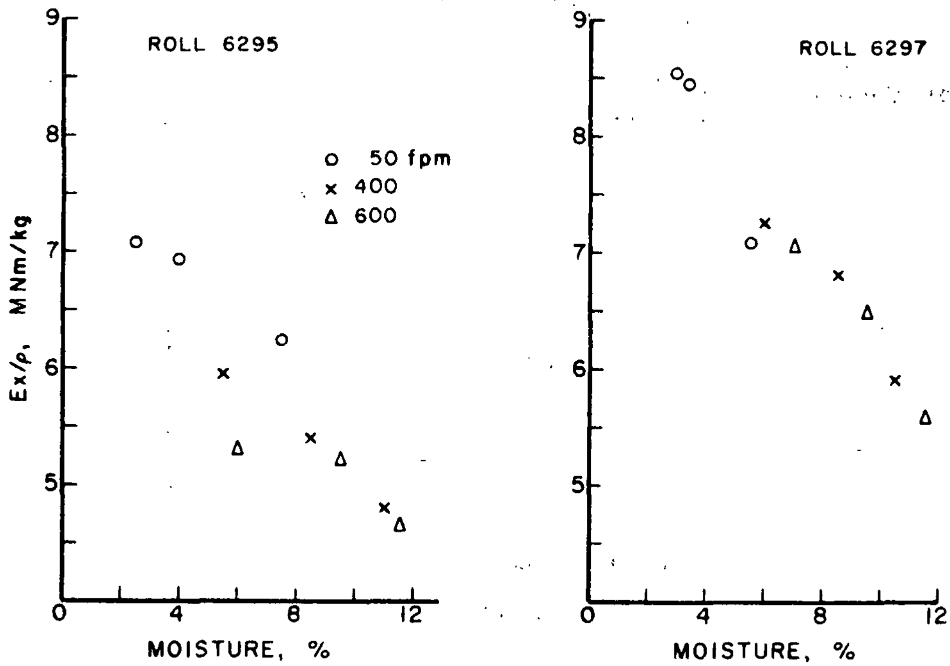


Figure 15. Effect of medium web moisture on stiffness, neglecting temperature variations.

For the 26-lb mediums, raising the moisture content of the web from about 6% to about 9.5% gave increases in flat crush of about 7 to 15% (see Fig. 16). Temperature increases accompanied the moisture content increases and probably helped the forming. Further increases in moisture content to about 11+% did not consistently give additional flat crush improvements.

The 33-lb medium exhibited increases in flat crush of about 20% as the moisture was raised from 4 to 7-8% and as the web temperatures were increased from 100-130°F to 143-178°F. Raising the moisture further to 11-11.5% at about the same temperatures gave only a small additional increase in flat crush (Fig. 16).

In the case of the 40-lb medium the additional showering gave only small increases in flat crush. The flat crush levels seem low on a per pound of fiber basis as discussed in the Project 2695-23 Progress report. It appeared that flat crush failure occurred as the second arch started to collapse as discussed in our work on Project 2695-23. SEM photos suggest that delamination occurs, which limits the attainable strength.

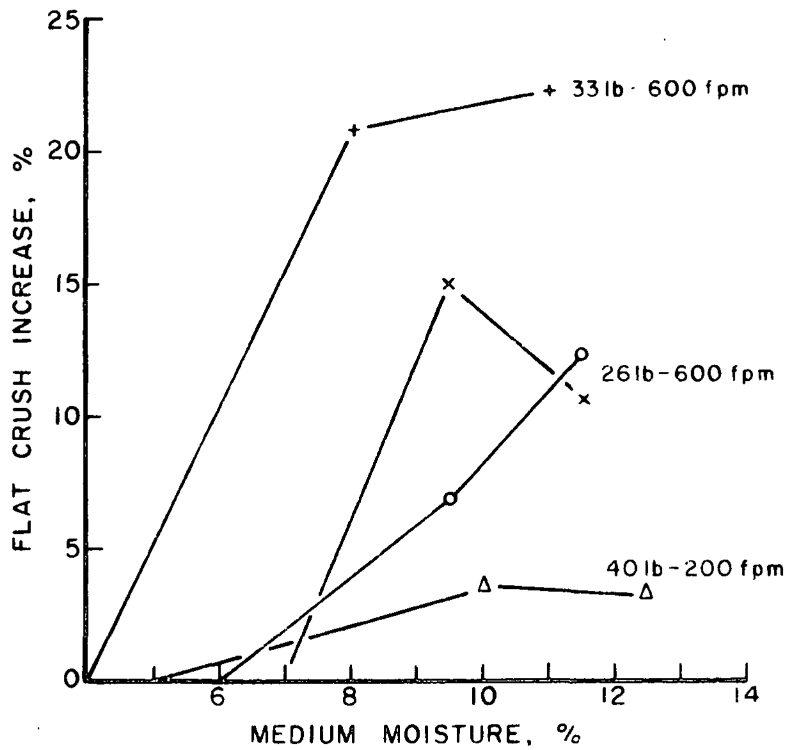


Figure 16. Effect of medium moisture after showers on flat crush (temperature effects neglected).

Limited trials were also carried out on a 26-lb medium to (a) pre-moisten the web and (b) apply a light hot water spray before the steam showers. Neither approach appeared to make any great improvement in medium performance.

The single faced ring crush results show slight decreases with increasing speed which are somewhat more pronounced with the heavier weight mediums. The steam showers also help retain more CD compressive strength.

Figure 17 shows that E_z/ρ exhibits a shallow maximum in the 6-8% moisture range. In contrast, E_x/ρ decreases steadily as moisture increases.

The different E_z/ρ behavior may reflect caliper effects as moisture changes. Disregarding this possibility, it might be speculated that maximum flat crush performance is associated with the shallow maximum because strength retention is favored by higher ratios of E_x/E_z as discussed earlier.

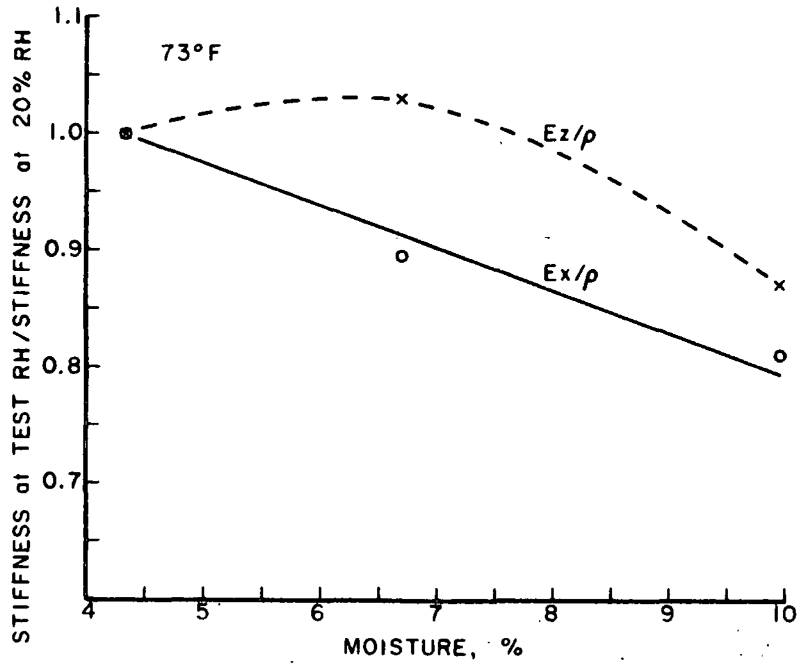


Figure 17. Effect of moisture content on elastic stiffness.

LITERATURE CITED

1. Whitsitt, W. J.; Sprague, C. Project 3396, Report One to the Members of The Institute of Paper Chemistry.

2. Gottsching, L.; Otto, W., Papier 30(10):417(1976); 30(11):457(1976); 31(2):45(1977); 31(3):85(1977); 31(4):129(1977); 31(5):169(1977).

3. Toroi, M.; Kolhonen, E., Pulp Paper Mag. Can. 77(10):T194(1976).

4. Thomas, C. E. 1979 Corrugated Containers Conference Proceedings, TAPPI, Atlanta, p. 39-48.

5. Nordman, L.; Toroi, M., Papier-Kunstoff Verarb. 5(10):7(1970); Boxboard Containers 78(4):94(1970).

6. McKenzie, A. W.; Yuritta, J. P., Appita 27(2):106(1973).

THE INSTITUTE OF PAPER CHEMISTRY

Carl N. Smith
Research Assistant
Paper Materials Division

William J. Whitsitt
Research Associate
Paper Materials Division

Gary A. Baum
Director
Paper Materials Division