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The Effect of Press Drying on Groundwood, Corrugated Material, and Various Mixes of Groundwood and Corrugated Material

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THE EFFECT OF PRESS DRYING ON GROUNDWOOD, CORRUGATED MATERIAL, AND VARIOUS MIXES OF GROUNDWOOD AND CORRUGATED MATERIAL

by

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ABSTRACT

Research was conducted to determine the effect of press drying on the physical properties of handsheets made from groundwood, corrugated material, and various mixes of groundwood and corrugated material. During this study, press dried handsheets were compared to conventionally dried handsheets.

There was a difference in handsheet properties as the blend ratio of corrugated-to-groundwood stock changed. Strength related properties were positively affected by the amount of corrugated material present for both press dried and conventionally dried handsheets. The press dried sheets had higher burst factor and tear factor as corrugated content increased. Burst factor, elongation, and tear factor increased with increasing corrugated material for the conventionally dried sheets.

Press drying was seen to be beneficial to strength development in handsheets. Tensile and bursting strength were greatly enhanced by press drying. However, press drying was detrimental to tearing strength and stiffness.

Increased bonding in the press dried sheets results in the higher breaking length and burst factor, and lower tear factor. The greater stiffness of the conventionally dried handsheets is caused by the higher caliper of these sheets compared to the press dried handsheets.

Keywords: Press drying; Conventional drying; Groundwood; Corrugated material; Strength properties.

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INTRODUCTION

The purpose of this study is to determine the effect of press drying on the physical properties of handsheets made from groundwood, corrugated clippings, and various mixes of groundwood and corrugated clippings. The bulk of previous research has been directed toward press drying of handsheets made from kraft cooks of various softwood and hardwood fibers with very little published reports on the use of groundwood or corrugated material.

Press drying is a method of drying paper which utilizes the simultaneous application of heat and pressure. It provides an effective method to maximize the bonding of unbeaten, high-yield pulps producing paper having the highest specific strength and stiffness for any given pulp furnish, softwood or hardwood. It has been shown to be especially effective on short, stiff, thick-walled hardwood fibers which still contain a high degree of its original hemicellulose and lignin content.

The decision to chose groundwood as a fiber source is twofold. One, groundwood is a high-yield pulp that has been subjected to very little refining. Secondly, during the production of groundwood pulp very little of the lignin or hemicelluloses are removed. Groundwood contains most of the lignin and hemicelluloses it initially possessed. Additionally, the harsh mechanical treatment of groundwood causes extensive

cutting and shortening of the fibers with little fibrillation. Thus it appears that groundwood is naturally suited for the press drying process.

The decision to use corrugated clippings is based on the fact that corrugated containerboard is composed of both softwood (in the linerboard) and hardwood (in the medium) fibers. The corrugated stock contains fibers produced from a chemical process that have been refined (or brushed) thus producing fibrils.

The reason to use various mixes of groundwood and corrugated materials is to examine if a certain blend of these will result in better properties than that obtained with just one of the fiber sources.

The handsheet properties to be studied include: tensile strength, percent elongation, burst, ring crush, stiffness, and tear.

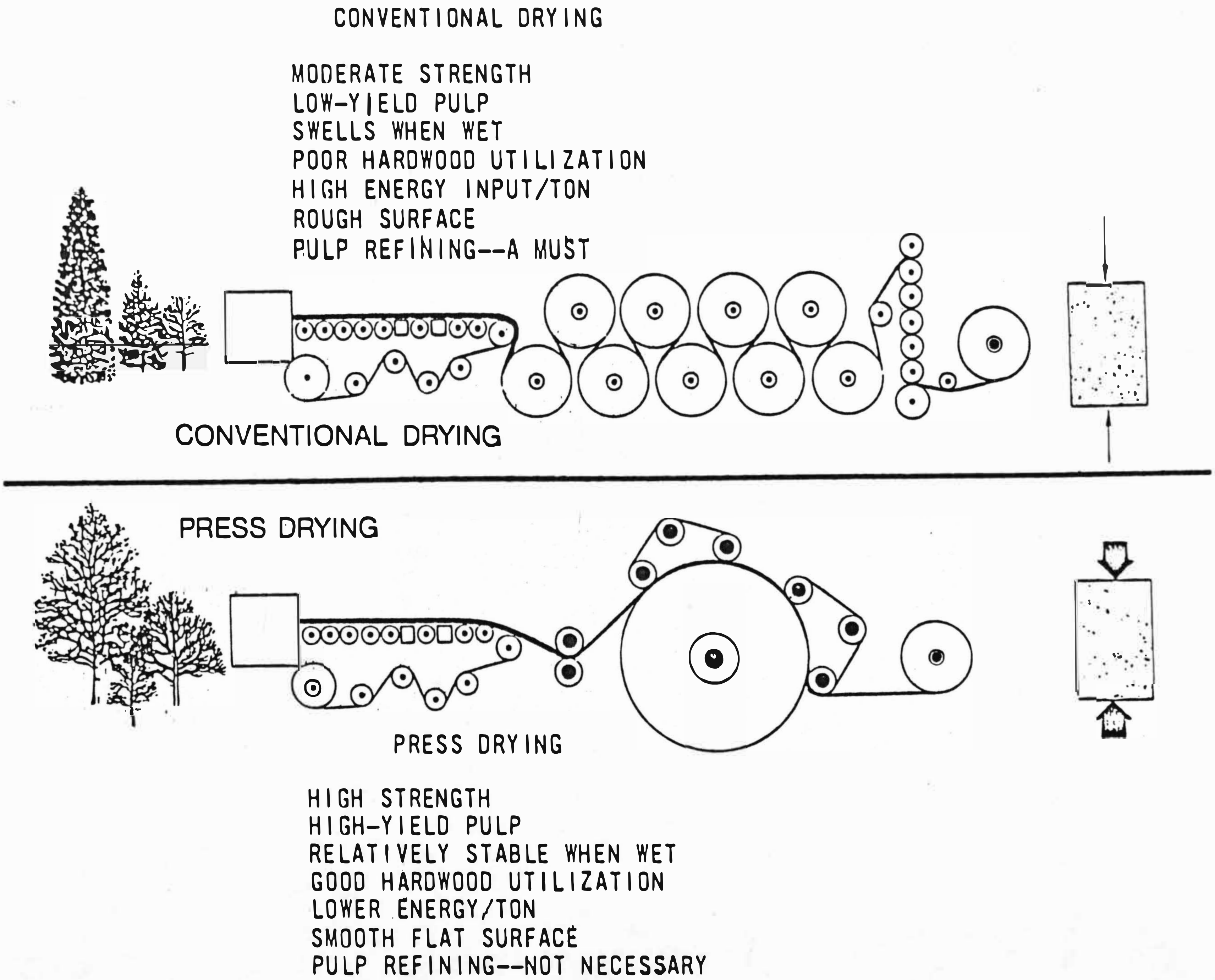
BACKGROUND AND THEORETICAL DISCUSSION

Press drying, originally termed "drying with Z-direction restraint," is a relatively new concept which utilizes the simultaneous application of heat and pressure during drying to bond pulp fibers together into high strength paper products (1). This is in contrast to the conventional methods which use heat and pressure separately (See Figure 1.) (2,3). The lack of pressure during conventional drying permits the fibers to spring-back thus optimum contact between fibers is not achieved during drying. The continuous high pressure exerted during press drying does not allow the fibers to spring-back.

Press drying was developed in 1973 at the Forest Products Laboratory in Madison, Wisconsin, under the direction of Vance Setterholm (4,5). The Forest Products Laboratory is a division of the Forest Service, U.S. Department of Agriculture and is maintained in cooperation with the University of Wisconsin-Madison (1,6). The first published report was presented in April 1975 and involved the use of softwoods. A subsequent report on hardwood use was published in 1977. Initial studies focused on work with handsheets. A pilot plant paper machine incorporating press drying was installed in 1979 (4,5).

Press drying would allow the use of 100% hardwood pulp in the production of linerboard for corrugated

Figure 1. Basic Models of Conventional and Press Drying Processes.



containers (6,7,8). As of now, most linerboard is made primarily from softwoods with possibly small amounts of hardwood fibers added. The majority of the corrugated medium is produced from hardwood fibers. With press drying the potential exists to produce a corrugated container (i.e., liner and medium) from 100% hardwood fibers.

Resource and Economic Benefits

For each cubic meter of hardwoods used, three cubic meters of softwoods are used in the U.S. forest industry (9). The forests of the U.S. are approximately 45% softwoods and 55% hardwoods (4,5,9). So 45% of our resources supplies 75% of our production requirements. Over half of the timber used in the U.S. goes into the manufacturing of pulp and paper, and of this, 25% is used to produce linerboard for corrugated boxes. Thus 12.5% of the total timber used in the U.S. is for the production of linerboard (3,6).

Since press drying offers the potential to use 100% hardwood fibers in the production of linerboard, this process could substantially lessen the demand on softwood fibers, allowing them to be used in other areas such as buildings.

In many areas, especially the Midwestern and Eastern parts of the U.S., hardwood pulpwood is generally more readily available and at significantly lower prices than softwood pulpwood (3).

Press drying offers several economic advantages over conventional linerboard manufacturing processes and these advantages are summarized as follows (3,8):

1. It permits the substitution of lower cost hardwood pulp in linerboard manufacture, resulting in comparable or higher quality linerboard.

2. It permits the use of less refined, higher yield pulps without sacrificing product quality. Less refining results in less energy usage. Higher yield increases the amount of product obtained per ton of wood used.

3. It could reduce the total process energy requirements, due to less refining as mentioned above and the paper enters the dryer section at a lower moisture content. Pressing water out of the web uses only 5% of the energy required by conventional drying (4).

Development of Press Drying

Setterholm and others' initial research focused on utilizing higher-yield softwood pulps and less refining (1). Kraft pulps of various yields (49, 55, and 60 percent) were produced from Douglas-Fir chips. Linerboard weight handsheets of 205 g/m^2 (42 $lb/1000\ ft^2$) were made from these pulps and dried on a laboratory heated press. These press dried handsheets were compared to conventional air dried sheets.

At all yields the bursting strength, ring crush, edgewise compression, tensile strength, and modulus of

elasticity were all higher for the press dried sheets than the control sheets. The only property that was not improved was tear strength. Further analysis of the results showed that the strength properties (except tear strength) of the high-yield unrefined pulp were higher than that obtained from refining the low-yield pulp. It was seen that press drying is more applicable to high-yield, lightly refined fibers than to low-yield, highly refined fibers (1,5). The above results enticed them to determine if sheets made from hardwood pulps would benefit from press drying.

In the next experiments, Setterholm and others prepared a series of kraft cooks of northern red oak and sweetgum (10). Pulp yield and freeness levels were varied. Again, linerboard weight (205 g/m^2) handsheets were made and some were press dried and some conventionally dried. The press dried sheets were dried under 400 psi pressure at a temperature of 400° F for 30 seconds. Handsheets were made from the two hardwood species and from hardwood-softwood mixtures. The data from this report was compared to data from the previous report on handsheets made from a kraft pulp of Douglas-fir.

The press-dried handsheets were found to be more dimensionally stable, and all strength properties (especially tensile and burst) were higher than the conventionally dried sheets. The high-yield handsheets made from Sweetgum performed better than the press dried handsheets made from high yield Douglas-fir. The high-yield

handsheets made from Sweetgum were far superior to the low-yield, conventionally dried handsheets for burst, ring crush, tensile strength, and modulus of elasticity. Little benefits were gained from making handsheets from hardwood-softwood blends. It was seen that press drying is inherently more applicable to high-yield hardwood pulp fibers with very little refining.

The moisture content of the sheet prior to press drying was found to be critical to the strength development of the sheet. A sheet press dried from an initial moisture content of 65% was superior in strength to one dried from a 40% initial moisture content. Thus the key is to apply heat and pressure to a sheet with sufficient moisture present.

Drying and heat transfer characteristics were examined next at the Forest Products Laboratory. They studied the drying and heat transfer rates on their laboratory static heat press in an attempt to quantify these rates to aid in the design of a continuous prototype press drying apparatus (11). Handsheets of 100 g/m^2 were made from a 60% yield unbleached kraft pulp of northern white oak.

Several variables were examined in this study. Press temperatures were varied from 250° F to 550° F, press pressure was varied from 2 to 400 psi. The initial moisture contents of the sheets before press drying was varied from 60 to 45 percent moisture.

Drying rates and heat transfer coefficients were found to increase with increasing Z-directional pressure up to 60 psi then level off through pressures up to 400 psi. Drying rates and heat transfer coefficients increased with increasing platen temperatures of 250°F to 550° F. Higher drying rates were observed for sheets at a higher initial moisture content when press dried. It was decided that better thermal contact with the wetter sheets resulted in the higher drying rates. The final conclusion of this study was that ". . . diffusion of the saturated water vapor (generated within the sheet during drying) may be the limiting factor which governs drying rate during press drying of linerboard." (11).

Michell, Seth, and Page of the Pulp and Paper Research Institute of Canada examined the effect of press drying on the structure of the paper (12). They devised a method for producing press dried sheets that had similar surface texture and internal structure as conventional sheets. Using the Taylor plot they showed that their handsheets had similar surface roughness. The handsheets also had similar scattering coefficients and air resistance. It was seen in this study that the press dried sheets attained a lower moisture content than the conventional sheets. It was thought that this lower moisture content of the press dried sheets was due to the high temperatures used in press drying. They confirmed this by exposing the conventional sheets to elevated temperatures in an oven.

Gunderson of the Forest Products Laboratory (FPL) reported on a study done comparing continuous and intermittent press drying and the effect of temperature (13). Two types of materials were used as a fiber source. Kraft pulp at 60% yield made from red oak was made on the FPL pilot plant machine. Recycled corrugated stock was slushed in a hydropulper and handsheets were made in a British Sheet Mold. Sheets were compared on an equal density basis.

It was found that continuous restraint resulted in higher bursting strength, tensile strength, compressive strength and bending stiffness than intermittent pressing. It was also found that continuous restraint is more effective in developing sheet density. Increasing the drying temperature from 160° F to 290° F during press drying resulted in improved brusting strength, tensile strength, compressive strength, wet tensile strength, and extended the water drop absorption time.

Softwood Versus Hardwood Use

One reason that softwood fibers are more desireable as papermaking fibers (over hardwood fibers) is that the structural or fiber morphology properties of softwoods are inherently better than those of hardwoods (2,14). Softwood fibers are typically long, flexible, thin-walled fibers. These fibers collapse into ribbons thus providing higher contact areas between the fibers, resulting in good fiber bonding and high sheet strength properties.

The hardwood fibers are predominantly short, thick-walled fibers which are too stiff and inflexible to provide good contact area between the fibers. This results in insufficient fiber bonding and weak paper. Also, the amount of fines generated with hardwood pulps cause drainage problems on conventional paper machines. The wet-web strength of paper made from hardwood pulps is very low. Press drying offers the potential to overcome the above disadvantages of hardwood fibers.

During the initial studies of press drying, it was found that the difference between properties of conventionally dried and press dried increased with increasing fiber stiffness (1,5). Therefore, it was concluded that press drying is more applicable to high-yield lightly refined fibers than to low-yield, highly refined fibers. The net result is that paper is produced having the highest specific strength and stiffness attainable for any given pulp furnish.

In short, press drying provides an effective method to maximize bonding of unbeaten, high-yield, stiff, thick-walled hardwood fibers, especially the underutilized high density oak species (1,2,5,14,15,16).

Bonding in Press Dried Sheets

The mechanism of interfiber bonding in press dried sheets was examined by Horn (17). Unbeaten high-yield Redgum pulps were used for this analysis.

As is commonly known, high-yield pulps are composed of three natural polymers viz., cellulose, hemicellulose, and lignin. In a report by Goring, it was found that hemicellulose and lignin has a tendency to soften and flow under the application of heat and pressure, while cellulose does not exhibit any significant tendency to soften and flow (18). The lignin and hemicellulose possess thermal softening temperatures which are dependent upon the absorbed moisture content. The absorbed water lowers the softening temperature of the lignin and hemicellulose found on the fiber surface (17). The presence of high amounts of lignin retards the initial flow and adhesion of hemicellulose (18).

The simultaneous application of heat and pressure during press drying promotes the flow of hemicellulose and lignin on the fiber surface. It was determined that the hemicellulose bonds formed during press drying are primarily responsible for the high strength properties of press dried sheets. It was concluded that the lignin present does not contribute to sheet strength but acts as a protector of the hemicellulose bonds. The lignin

"seals" the hemicellulose bonds by making them less accessible to moisture. However, the lignin does contribute to the creep properties of press dried sheets (17).

In a later study, Horn examined the role of parenchyma cells in the press drying of high-yield pulps (19). High-yield kraft pulps made from white oak were used. Oak was chosen due to the high percentage, by weight, of parenchyma cells present in these pulps. In conventional dried sheets, the presence of parenchyma cells were found to be detrimental to sheet strength.

In Horn's study it was found that removal of parenchyma cells from the pulp decreased the sheet strength (burst and tensile) but increased the sheet's modulus of elasticity. It was determined that the presence of parenchyma cells are beneficial to the sheet strength of high-yield press dried sheets.

Parenchyma cells contain both hemicellulose and cellulose, however, they have a higher hemicellulose content. The parenchyma cells are considered to act as a bonding agent due to their high hemicellulose content (19).

SUMMARY

The Potential of Press Drying

As mentioned, press drying is a method of drying short, stiff, dense hardwood fibers under a compressive force. This force results in greater conformability and interfiber bonding. Press dried sheets have higher tensile strength, bursting strength, higher edgewise compression and ring crush, and is more dimensionally stable when exposed to cyclic humidity than conventionally dried sheets. Press drying will allow the use of underutilized hardwood fibers, and higher yield, less refined pulps. It also offers the potential to reduce energy costs (2,4,5,8,14).

Problems

Despite all of the potential advantages there remain manufacturing problems that must be conquered before press drying will become commercially applicable. This process must be able to be applied to high speeds and outputs. Fabrics must be developed which can withstand high nip pressures and temperatures. Drying cylinders with more applied energy are required. The potential exists that the web may want to stick to these cylinders, and the cleaning of the drier cans may pose a problem (7).

The Future

To ensure the future of press drying the process will have to be refined and first proven it can work on a pilot plant scale. This is currently being pursued at various places including the U.S. Forest Products Laboratory, and St. Anne's Board Mill, Bristol (7). The Boxboard Research and Development Association (BRDA) has also taken a substantial interest in this area. The above mentioned manufacturing problems will have to be solved before commercial application will become feasible.

Research has been directed toward making kraft linerboard and other heavy-weight sheets from hardwoods such as oak. Some studies have included the use of old corrugated stock, newsprint, and other fiber sources, but there have been few published reports in these areas (12,13,16).

It is thought that press drying may offer some advantages in reducing sizing costs (4). The presence of the hemicellulose and lignin provides a slightly nonporous surface for printing thus little or no sizing may be required. The smoother surface and better dimensional stability of the press dried sheets may eventually make it an attractive alternative for producing white paper grades (5).

Press drying on a commercial scale is a possibility but there exist many manufacturing and engineering problems that must be solved. As stated above, press drying will have to be proven first on a pilot plant scale before attempting commercial application.

EXPERIMENTAL

Materials

Two different types of materials were used in this study of press drying, viz., groundwood and corrugated material. The groundwood source was obtained from butt-rolls of newsprint from a local newspaper organization. Sheets of single wall corrugated board were obtained from a commercial corrugating container company.

The various mixes used were 100/0, 80/20, 60/40, 50/50, 40/60, 20/80, and 0/100 percent groundwood/percent corrugated material, respectively. All stock was fiberized in a Morden Slushmaker for two minutes. Linerboard-weight (205 g/m^2, 42 $lb/1000\ ft^2$) handsheets were formed in a Noble and Wood handsheet mold. The wet sheets were double pressed to 50% moisture content before drying. The sheets were then press dried on a laboratory static press or conventionally dried on the Noble and Wood dryer can. All handsheets were equilibrated at 73° F and 50% relative humidity. A detailed description of the above is given in the following section.

Procedure and Equipment

Every run of the various mixes were performed following the same procedure.

An equivalent of 500 g oven dried (OD) fiber was weighed out, ripped into small pieces and soaked in 14.7 liters of water until the stock was softened. The softened stock was dumped into a Morden Slushmaker, diluted to 20 liters (for a 2.5% consistency furnish) and fiberized for two minutes. This time was sufficient for complete dispersion of the fibers.

Approximately 6.5 liters of the 2.5% consistency stock was poured into the Noble and Wood proportionater. The proportionater was diluted to 19 liters for a 0.85% consistency stock. A 1 liter sample of this stock was used to pour into the Noble and Wood handsheet mold. Preliminary handsheets were made to ensure the correct consistency stock was in the proportionater. If not, calculations were made and the stock was corrected accordingly. About 10 handsheets were made from this stock for testing, and 5 were press dried and 5 were conventionally dried.

Since the Noble and Wood procedure makes sheets 8 inches X 8 inches, a 8.46 g OD handsheet was required to obtain a basis weight of 205 g/m^2 (42 $lb/1000\ ft^2$). The handsheets were formed on 150-mesh screens.

After the handsheets were formed, they were wet-pressed to 50% moisture content before drying. Double-pressing was required to obtain a 50% moisture content after pressing. Double-pressing consisted of first wet-pressing the wet sheet (still on the screen) between felts, carefully peeling the pressed sheet off the screen, placing the web between two blotters, and pressing this sandwich between the felts. A preliminary investigation revealed that the consistency of the wet sheet after pressing the first time was 37.4%, and after double-pressing the desired 50% consistency sheet was realized. After the sheets were double pressed they were weighed, dried, and weighed again to determine the actual consistency of each sheet after double-pressing. Of the 10 handsheets made, 5 were press dried and 5 were conventionally dried.

Equipment

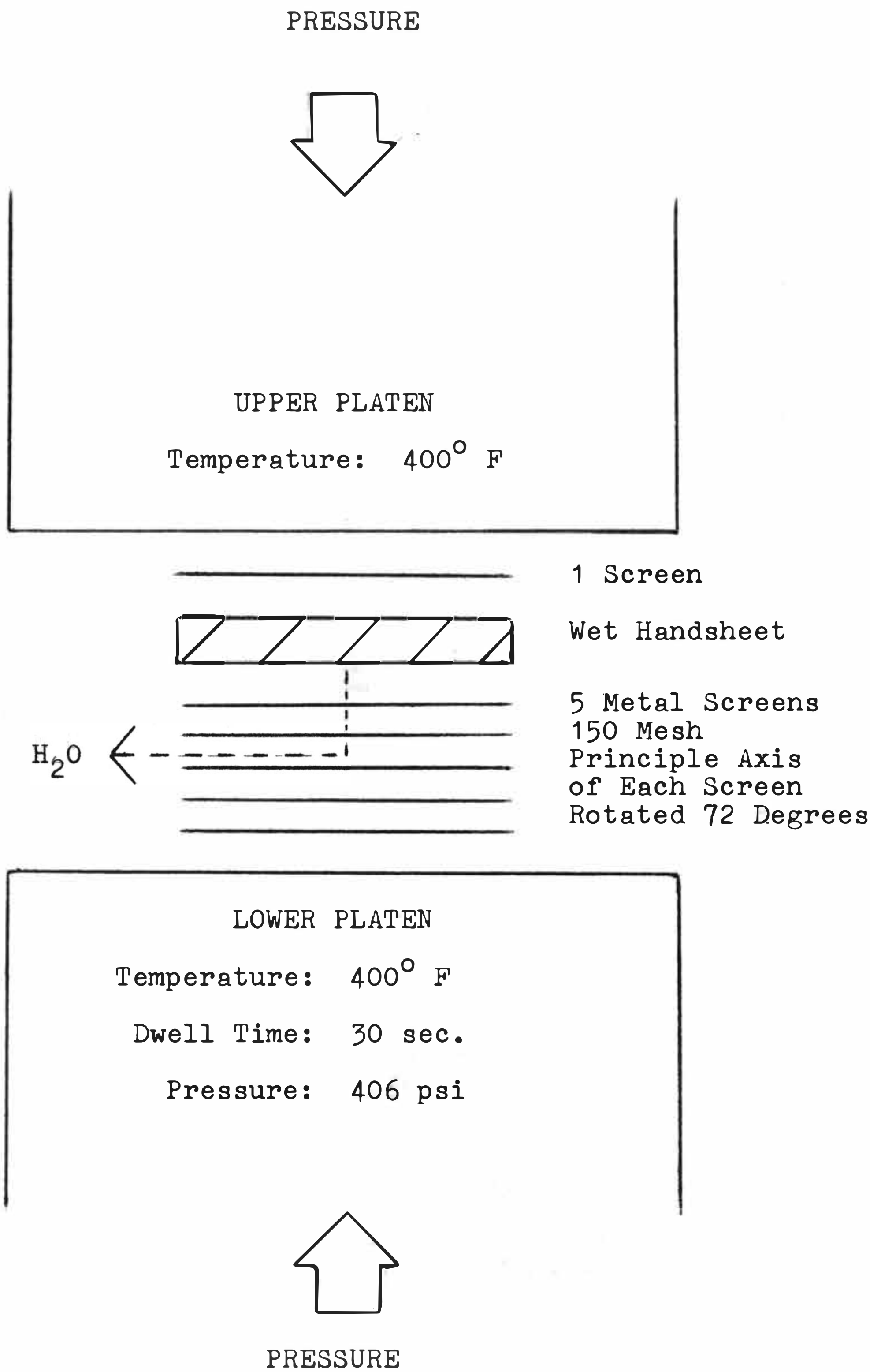
The Noble and Wood dryer can is essentially a drum dryer internally heated with steam. The dryer can temperature was 240^{o} F and the sheets were passed through the dryer twice at a slow speed (an approximate dwell time of 2 minutes) for complete drying of the sheets. The pressure exerted by the nip formed by the drum and dryer felt is considered negligible compared to the pressure used in press drying.

The press drying was done on a laboratory static press (See Figure 2). Basically, the press consists of steel, electrically heated upper and lower platens. Each platen has its own controls including an adjustable thermoswitch and a thermometer. The thermoswitches (located on the backs of each platen) allow for independent, precise temperature control of each platen. The upper platen is stationary and the lower platen is hydraulically loaded to exert the necessary pressures.

The handsheets were dried under 406 psi of pressure for 30 seconds at an upper and lower platen temperature of 400° F. Initially it was intended to use 400 psi pressure, but on the 8 X 8 inch (64 in^2) handsheets a gauge reading on the press of 12.8 tons would have been required. The divisions on the gauge would not have allowed consistent pressure application due to tester's error. Thus a 13.0 tons (for 406 psi of pressure on the sheets) reading was used to minimize error.

The wet sheet was placed between one 150-mesh screen on the top and five 150-mesh screens on the bottom (See Figure 2). The screens allow moisture to escape from the wet sheet and provides a cushion for more uniform pressure distribution (10). The principle axis of each of the bottom screens were rotated approximately 72 degrees to avoid a wire pattern on the sheet. However, this was not too successful. The sheets still

Figure 2. Laboratory Static Press Used In Press Drying.



developed a pronounced wire pattern due to the knuckles of the wires.

It is recommended for anyone desiring to pursue the topic of press drying to utilize a method which would minimize the wire pattern. One such method was examined by Michell, Seth, and Page of the Pulp and Paper Research Institute of Canada (12). It is suggested that the interested reader or potential researcher examine their method which is presented in their paper "The Effect Of Press-Drying On Paper Structure" (12).

Testing

All handsheets were conditioned in the constant temperature and humidity room at 73° F and 50% relative humidity for a minimum of 24 hours before testing.

The thickness of the handsheets was measured using a motor-operated dial micrometer. Tensile strength and percent elongation test were conducted in the Instron tensile tester. The internal tearing resistance was measured using the Elmendorf tear tester. The stiffness of the handsheets was measured using the Taber stiffness tester. The compression resistance of the sheets was measured using the ring crush tester. Bursting strength was measured using a standard mullen tester. All above tests were conducted according to their respective TAPPI Standard Methods, viz., Thickness, T 411; Tensile and Elongation, T 494; Tear, T 414; Stiffness, T 489; Ring Crush Test, T 472; Burst, T 807.

RESULTS AND DISCUSSION

The overall test results are presented in Tables 1-3. The average sheet weights on an oven dried basis and at equilibrium conditions are presented, and a percent moisture content was calculated for the press dried sheets and conventionally dried sheets for each run. The basis weight is also given on an OD basis and at equilibrium conditions. The OD basis weights were required to calculate the various factors, i.e., tensile factor, tear factor, and burst factor. The values for equilibrium conditions are given because the presence of moisture in the sheets will effect test results and its effect should not be neglected when comparing results. Figures 5-10 are graphs plotting the various test results (e.g., tensile factor, ring crush, stiffness, etc.) versus grade mix (e.g., 100% GW/0% corrugated, etc.).

Moisture Content

The handsheets were weighed on an oven dried (OD) basis and after the sheets reached equilibrium conditions. A percent moisture content was calculated as follows:

$$\frac{\text{(Equilibrium wgt. - OD wgt.)}}{\text{OD wgt.}} \quad \text{X } 100$$

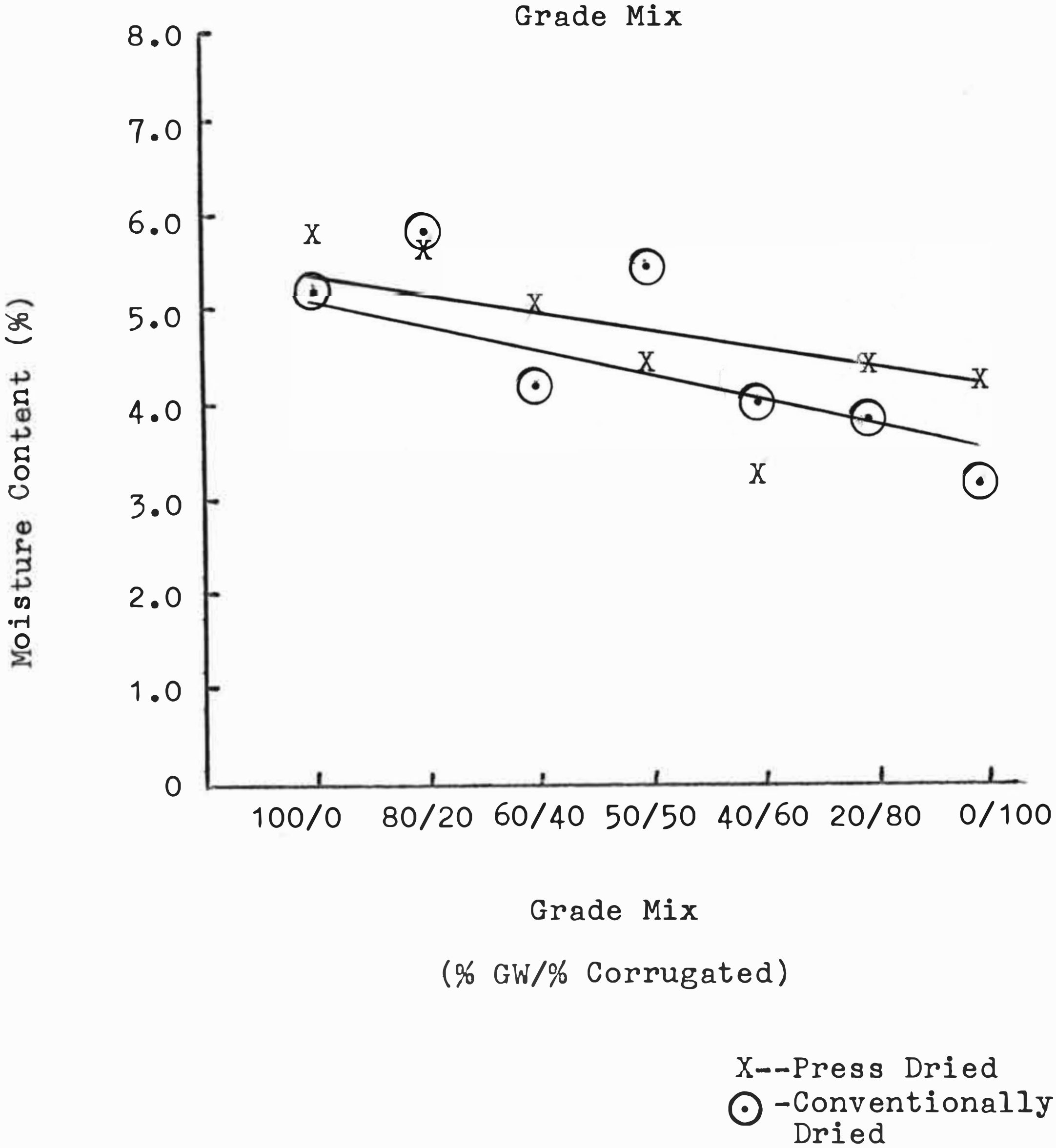
Figure 3 is a graph of percent moisture content versus grade mix and includes press dried (PD) and conventionally

FIGURE 3.

Percent Moisture Content

Versus

Grade Mix



dried (CD) sheets. The PD sheets show a slight decrease in equilibrium moisture content as the amount of corrugated stock increases. Two possible factors may contribute to this decrease in moisture content. First, groundwood fibers are from a mechanically treated pulp and the corrugated material is from a chemically treated pulp. There is a distinct difference in the bulk of these two, with the groundwood having a higher bulk. This higher bulk will contribute to the moisture absorbancy of the paper. Secondly, this trend may be attributed to the presence of hardwood fibers in the corrugated stock (as oppossed to groundwood which is usually made primarily from softwoods). The short hardwood fibers may cause the surface of the sheet to close up more than softwoods thus not allowing moisture to enter the sheet. The data for the CD sheets is too erratic and no general trends can be seen.

No definite conclusions can be drawn on the difference in equilibrium moisture contents between the PD and CD sheets. This is a surprising result because numerous studies have shown that PD sheets will attain a lower equilibrium moisture content than CD sheets. These studies have stated that the flow of lignin in press dried sheets (as a direct result of the high temperature and pressure) "seals" the hemicellulose bonds which makes them less accessible to moisture (17).

Caliper

The thickness of all handsheets was determined using a motor-operated dial micrometer. Figure 4 shows that for CD sheets there is a decrease in caliper as the amount of corrugated stock increases. There is a 13.1% decrease in caliper between the CD sheets that are made from 100% groundwood (GW) and those made from 100% corrugated material. This can be attributed to the higher bulk of the sheets made from 100% GW fibers.

There was virtually no change in the thickness of the PD sheets at the various grade mixes with values ranging from 11.7 to 12.0 points (See Table 1.). This narrow range can be ascribed to the high pressure (406 psi) and temperature (400° F) utilized during PD; all of the fibers have collapsed.

Bursting Strength

The bursting strength of the handsheets was measured in accordance with TAPPI Standard T 807. Burst factor was calculated by the following equation:

$$\frac{(70.3) \text{ X (bursting strength, psi)}}{\text{(OD grammage, g/m}^2\text{)}}$$

Burst factor was used instead of bursting strength values (in psi) to minimize the effect of basis weight differences on the bursting strength values.

FIGURE 4.

Caliper Vs. Grade Mix

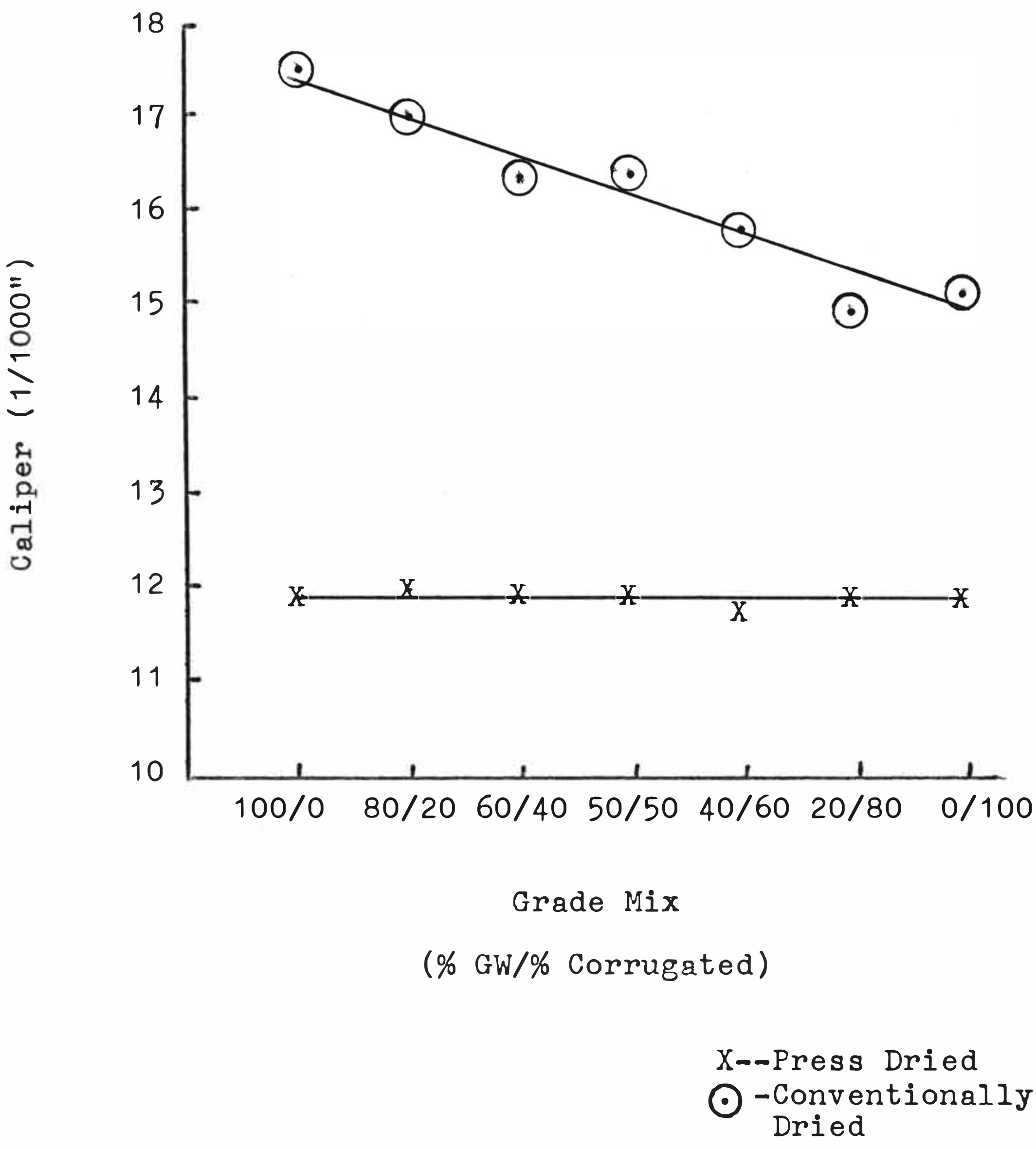


TABLE 1

Grade Mix (% GW/% Corrugated)		100/0[1]	100/0	80/20	60/40	50/50	40/60	20/80	0/100
Ave. Grammage OD Basis (g/m^2)	PD	205	205	206	205	204	203	204	204
	CD	204	205	206	205	204	202	207	203
Ave. Grammage @ Equilibrium Conditions (g/m^2)	PD	216	217	217	215	213	210	213	213
	CD	216	216	218	213	215	210	215	210
Moisture Pickup (%)[2]	PD	5.6	5.9	5.7	5.0	4.5	3.3	4.5	4.3
	CD	5.7	5.4	5.9	4.3	5.6	4.1	3.9	3.3
Ave. Caliper (1/1000 inch)	PD	12.3	11.9	12.0	11.9	11.9	11.7	11.9	11.8
	CD	17.4	17.6	17.1	16.5	16.5	15.9	15.1	15.3
Ave. Density OD Basis (g/cm^3)	PD	0.656	0.678	0.676	0.678	0.675	0.683	0.675	0.681
	CD	0.462	0.459	0.474	0.489	0.487	0.500	0.540	0.522
Ave. Density @ Equilibrium Conditions (g/cm^3)	PD	0.691	0.718	0.712	0.711	0.705	0.707	0.705	0.711
	CD	0.489	0.483	0.502	0.508	0.513	0.520	0.561	0.540

[1]Never been dried groundwood.

[2]Based on actual sheet weight averages, NOT calculated grammages.

Table 2. Comparison of properties[1] of press dried (PD) handsheets with conventionally dried (CD) handsheets made from groundwood (GW), corrugated material (corr.), and various mixes of groundwood and corrugated material. The average standard error associated with each test is given.

Grade Mix % GW/% corr.		Burst Factor	Ave. Std. Error	Breaking Length (km)	Ave. Std. Error	Elongation (%)	Ave. Std. Error
100/0[2]	PD[3]	23.8	1.9	5.81	0.21	2.32	0.10
	CD[4]	19.8	1.1	4.02	0.24	1.86	0.22
100/0	PD	31.6	2.0	5.52	0.48	2.18	0.34
	CD	24.0	2.6	4.35	0.39	2.09	0.32
80/20	PD	33.1	2.3	6.52	0.53	2.69	0.35
	CD	27.3	1.8	4.27	0.65	2.49	0.61
60/40	PD	34.3	2.4	6.83	0.93	2.93	0.51
	CD	28.1	1.8	4.23	0.33	2.20	0.20
50/50	PD	31.3	3.3	5.88	1.09	2.33	0.68
	CD	25.3	2.2	4.16	0.30	2.32	0.54
40/60	PD	34.9	1.6	5.69	0.39	2.43	0.08
	CD	27.0	2.8	4.36	0.37	2.51	0.31
20/80	PD	36.0	2.7	5.90	0.59	2.79	0.30
	CD	27.6	2.6	4.48	0.28	3.10	0.44
0/100	PD	36.6	2.9	5.94	0.95	2.61	0.66
	CD	28.7	2.1	4.28	0.47	3.18	0.43

[1]Tested at 73° F and 50% relative humidity.

[2]Never been dried groundwood pulp.

[3]Press dried handsheets.

[4]Conventionally dried handsheets.

Table 3. Comparison of properties[1] of press dried (PD) handsheets with conventionally dried (CD) handsheets made from groundwood (GW), corrugated material (corr.), and various mixes of groundwood and corrugated material. The average standard error associated with each test is given.

Grade Mix % GW/% corr.		Tear Factor	Ave. Std. Error	Taber Stiffness (g-cm)	Ave. Std. Error	Ring Crush (lbs)	Ave. Std. Error
100/0[2]	PD[3]	28.6	0.92	3.14	0.10	126	8.9
	CD[4]	38.4	2.0	6.96	0.54	127	9.6
100/0	PD	51.7	3.1	3.31	0.19	111	10.4
	CD	93.7	5.1	6.38	0.10	93.7	3.9
80/20	PD	63.6	6.6	3.24	0.21	133	2.8
	CD	95.6	3.9	6.48	0.47	94.8	7.3
60/40	PD	81.0	4.8	3.33	0.41	95.2	4.6
	CD	104	5.4	5.30	0.52	93.6	2.2
50/50	PD	79.4	2.5	3.17	0.24	101	8.5
	CD	114	6.4	5.45	0.50	89.2	4.6
40/60	PD	85.2	1.3	2.95	0.38	91.7	3.4
	CD	107	7.2	4.54	0.30	110	8.8
20/80	PD	89.7	3.4	2.99	0.21	130	9.0
	CD	124	7.2	3.97	0.65	87.3	4.3
0/100	PD	106	5.4	3.35	0.30	111	11.3
	CD	146	4.1	4.46	0.52	75.0	8.5

[1] Tested at 73° F and 50% relative humidity.

[2] Never been dried groundwood pulp.

[3] Press dried handsheets.

[4] Conventionally dried handsheets.

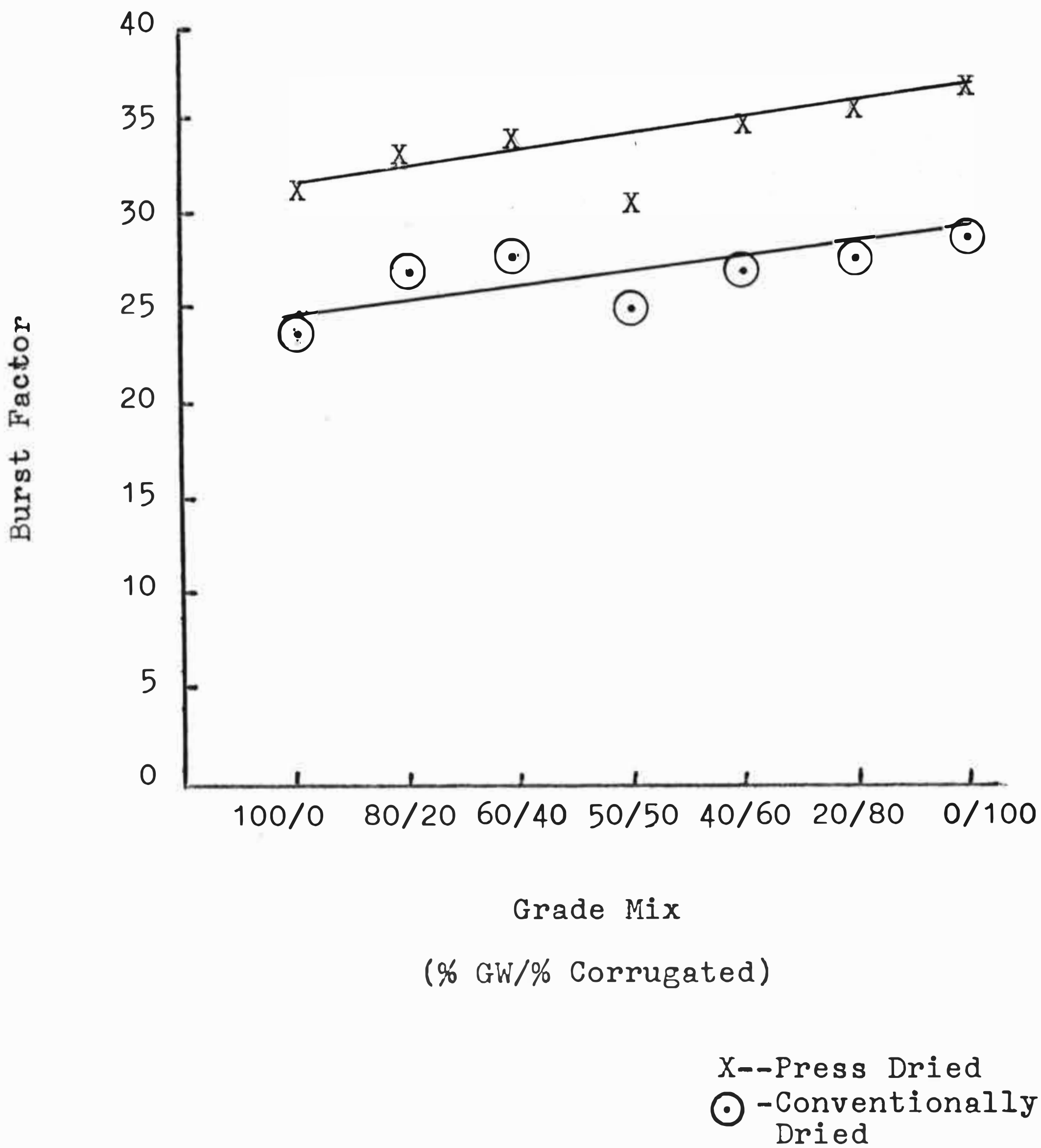
The results show that burst increases with increasing corrugated content for PD and CD sheets (See Figure 5). A 10.6% increase was realized for the PD sheets and a 5.1% increase for CD sheets, when comparing sheets made from grade mixes of 100% GW and 100% corrugated. This was expected due to the presence of longer and more refined softwood fibers present in the corrugated material, thus resulting in increased bonding.

The PD sheets had higher bursting strength than the CD sheets for all grade mixes. The PD sheets were an average of 26% higher than the CD sheets (with a low of 21% and high of 30%). Thus it was seen that press drying increases the bursting strength. This increase in bursting strength is because the simultaneous application of heat and pressure during press drying increases fiber flexibility, induces the flow of hemicellulose and lignin on the fiber surface, hence increased bonding. The lignin itself does not contribute to bonding but acts as a protector of the hemicellulose bonds (17).

As the amount of corrugated stock increased (thus % GW decreased) the percent increase of bursting strength was generally larger. The hardwood content of the corrugated material could be responsible for this. Press drying has been shown by Setterholm and others to have its greatest beneficial effects on hardwood fibers (10).

FIGURE 5.

Burst Factor Vs. Grade Mix



Tensile strength and Stretch

Tensile strength and percent elongation (stretch) were measured on the handsheets using an Instron tensile tester in accordance with TAPPI T 494. Breaking length was calculated by the following equation:

$$\frac{(200{,}000) \times (\text{tensile break load in kg on a 15 mm strip})}{(3) \times (\text{OD grammage in g/m}^2)}$$

The data presented in Figure 6 shows that the breaking length for CD sheets was affected very little at various grade mixes. The data for the PD sheets is a little erratic and no actual trends can be seen. If the two high data points were neglected, it appears that very little change in breaking length occurred. However, this would conflict with the aforementioned results for bursting strength, because tensile strength (like burst) is positively affected by increased bonding in paper.

The data does clearly show that the breaking length of PD sheets is higher than CD sheets. The PD sheets are an average of 40% higher than the corresponding CD sheets. This can be attributed to the increase in bonding that accurs in PD sheets over CD sheets.

From Figure 7., it is seen that for the CD sheets, percent elongation increases as the percent of corrugated stock increases. This is as would be expected due to the presence of longer softwood and more flexible fibers in the

FIGURE 6.

Breaking Length Vs. Grade Mix

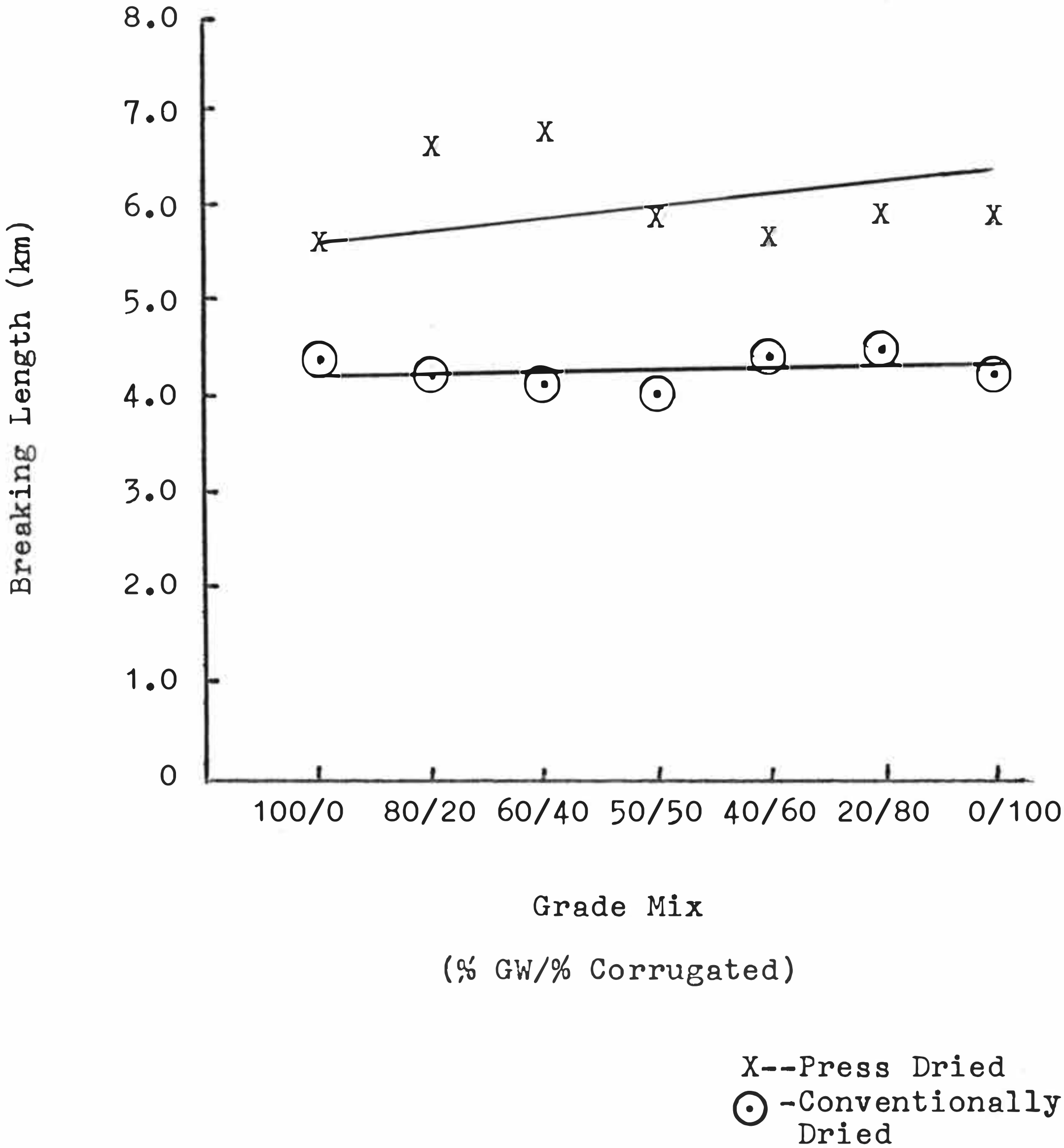
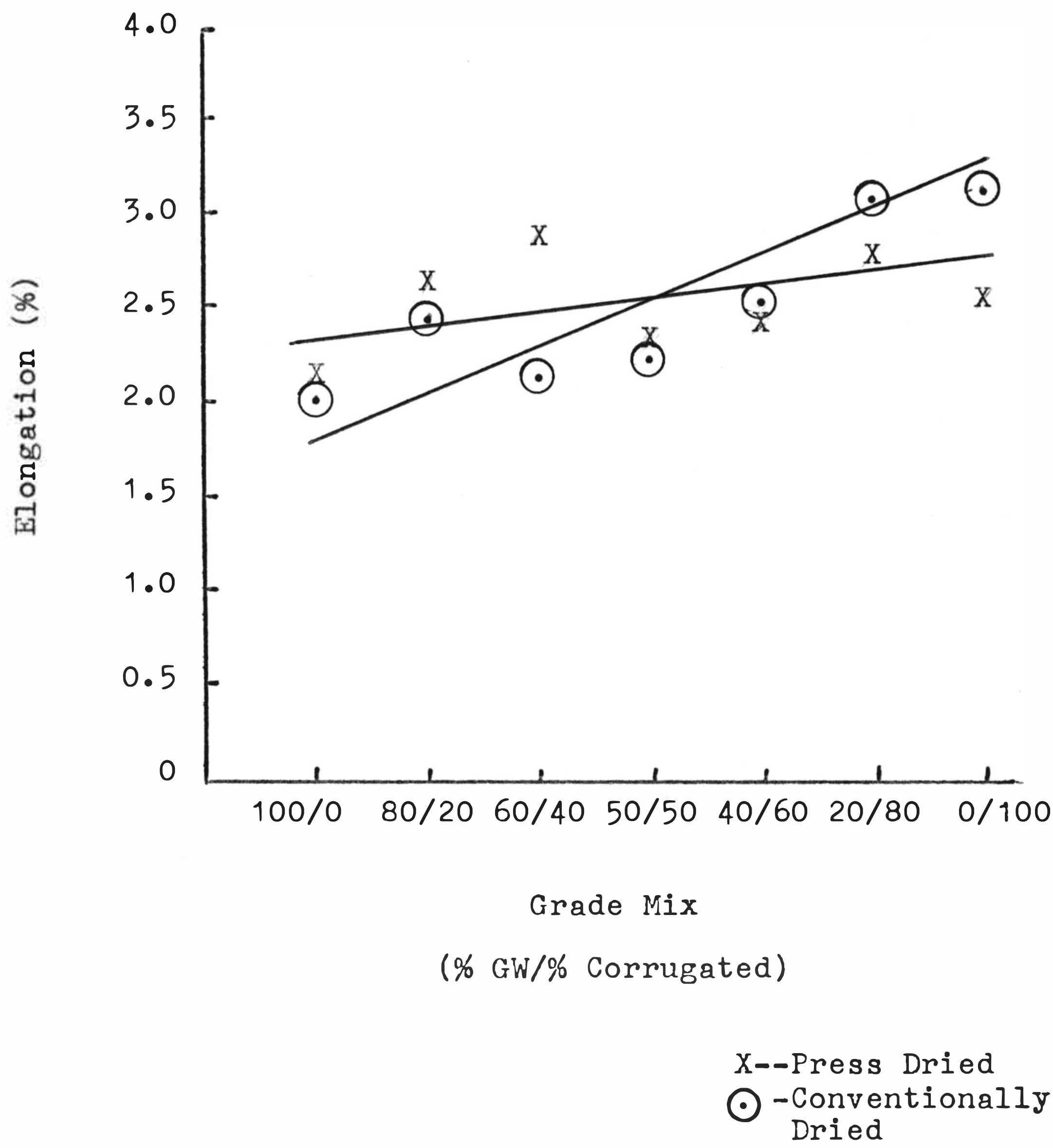


FIGURE 7.

Elongation Vs. Grade Mix



corrugated material and, of course, the fibers in the GW stock are exposed to harsher mechanical treatment resulting in the shortening of the fibers.

As with the breaking length, no general trend can be seen for the PD sheets with respect to percent elongation. However, it is interesting to note that the curves for breaking length and elongation exhibit the same type of behavior, i.e., an initial sharp increase followed by a decline followed by a slight increase in values.

Due to the erratic values of the PD sheets, no general trend can be seen by comparing the PD to the CD sheets for elongation. Some values are very close while the others are far apart.

Tear Strength

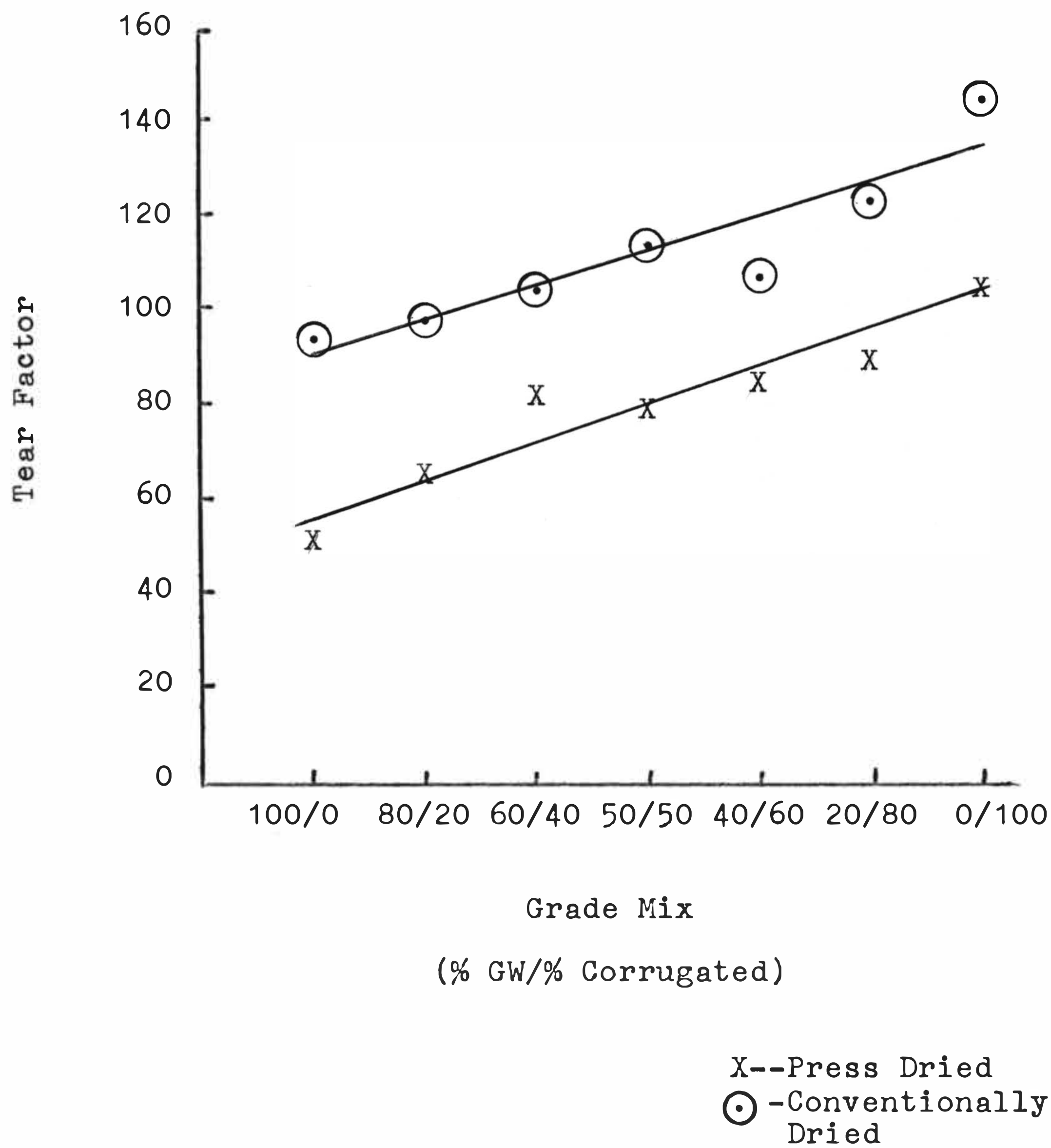
The internal tearing resistance of the handsheets was measured in accordance with TAPPI Standard T 414, utilizing an Elmendorf tear strength tester. Tear factor was calculated by the following equation:

$$\frac{(100)\ \text{X}\ (\text{Force in grams to tear a single sheet})}{(\text{OD grammage, g/m}^2)}$$

The results for tear factor (See Figure 8.) show an increase in tearing resistance as the amount of corrugated stock increases for both the PD and CD sheets. The

FIGURE 8.

Tear Factor Vs. Grade Mix



PD sheets at 100% corrugated material is 105% higher than the PD sheets at 100% GW. The CD handsheets at 100% corrugated are 55.8% higher than 100% GW.

At first the above results were a little disturbing. As stated for burst factor, there was a slight increase in bursting strength between the 100% GW and 100% corrugated handsheets. This increase in burst was attributed to increased bonding. The disturbing results are contained within this last statement. Tear strength is supposed to decrease with increased bonding in a sheet. However, after a little thought, it should be realized that the substantial gain in tear strength is not related to the increase in bonding (as mentioned for burst) but is due to the overall characteristics of the fiber sources themselves, viz., the GW is made from a weaker mechanical pulp whereas the corrugated stock is made from a pulp containing more long fibers.

When comparing the tearing strength of the PD and CD handsheets, it is seen that the CD sheets have a higher tearing strength than the PD sheets. As mentioned before, press drying induces flow of hemicellulose and increases bonding. This increase in bonding results in lower tearing strength for the PD sheets. Here is where the bonding becomes important whereas before the fiber source was the dominate factor.

Taber Stiffness

The flexural rigidity or stiffness of the handsheets was measured in accordance with TAPPI Standard T 489. This method utilizes the Taber Stiffness tester which measures the force required to deflect the free end of a sample 15 degrees.

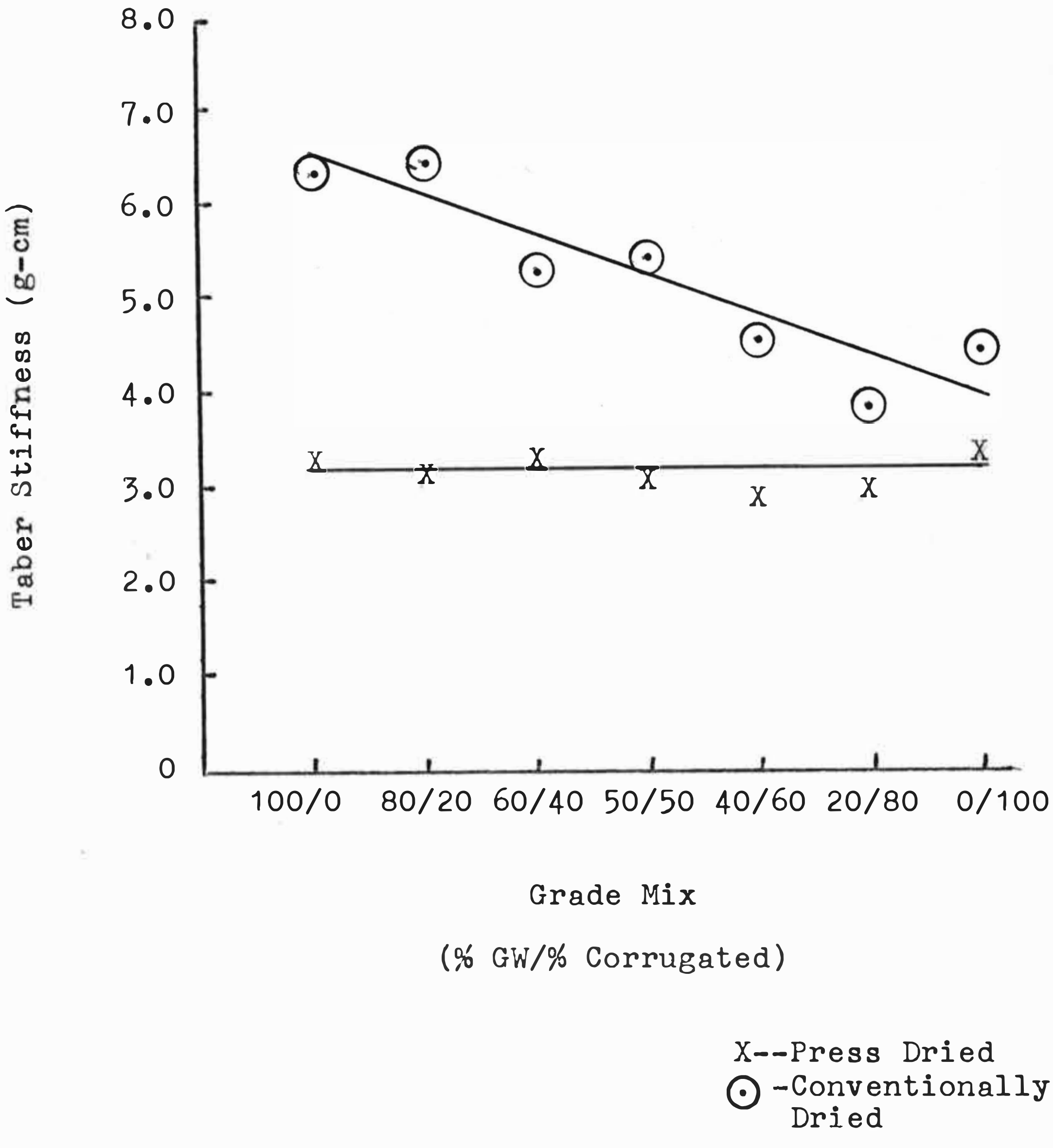
The results in Figure 9., show that for the CD sheets there is a decrease in Taber stiffness as the amount of corrugated material increases. Taber stiffness is greatly affected by caliper, with the stiffness being proportional to caliper. By examining Figure 2., it is seen that the caliper of the CD sheets decreased as percent corrugated material increased. This decrease in caliper is the cause of the decreasing stiffness of the CD sheets. Comparing the 100% GW and 100% corrugated grades, a 13.1% decrease in caliper resulted in a 30.1% decrease in stiffness.

The stiffness of the PD sheets did not change with the different grade mixes. By examining Figure 2., it is seen that there was no change in caliper as the grade mixes were varied. No change in caliper resulted in no change in stiffness.

The PD sheets had lower stiffness than the CD sheets at all grade mixes. This can be attributed to the lower caliper of the PD sheets. This result exemplifies the dependence of stiffness on caliper.

FIGURE 9.

Taber Stiffness Vs. Grade Mix



Ring Crush

The compression resistance of the handsheets was measured in accordance with TAPPI Standard T 472. The ring crush test measures the resistance of the speciman to edgewise compression. The load required to crush the sample is reported in pounds.

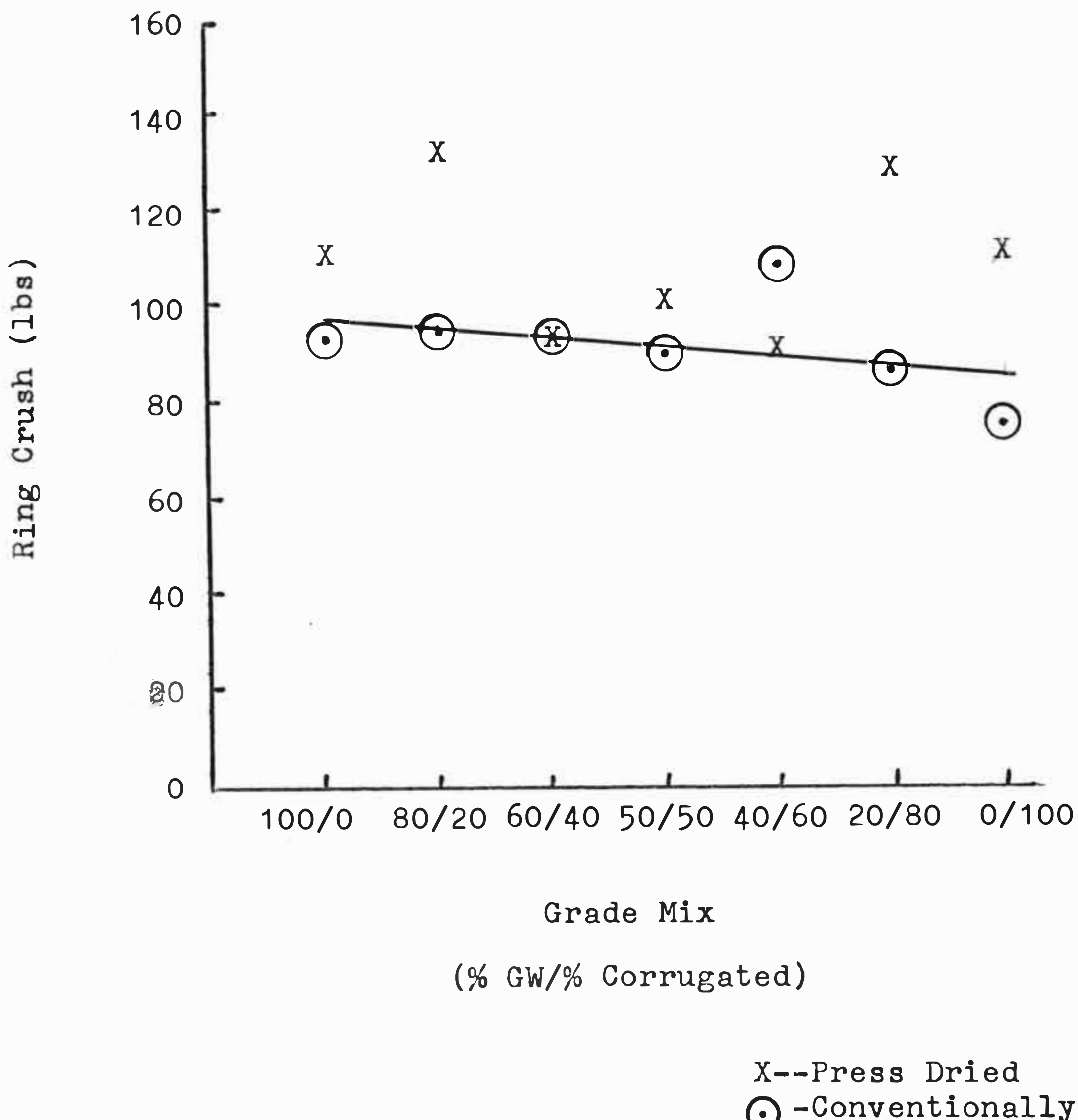
All of the values obtained from the ring crush test were erratic and no trends could be seen for the various mixes or between the PD and CD sheets (See Fiqure 10.).

Never-Been-Dried Groundwood

Some never-been-dried groundwood (NBD-GW) pulp was obtained for the purpose of determining if there would be a difference between the handsheets made from NBD-GW pulp and the GW that has been dried. After the handsheets were made, it was obvious that there would exist no basis for comparison due to the different origin of the two pulps. The NBD-GW handsheets were lighter in color and brighter, indicating a certain amount of bleaching was done on this pulp. The dried GW had been subjected to very little bleaching or none at all. The NBD-GW sheets were brittle. Testing was not done to determine the brittleness, but the NBD-GW handsheets would crack when folded, whereas the other GW sheets did not. It is felt that if a comparison is to be made between NBD-GW and once-dried GW, the samples

FIGURE 10.

Ring Crush Vs. Grade Mix



should be obtained from the same source, thus providing a basis for comparison.

However, it was still considered instructive to compare the PD handsheets to the CD sheets for the NBD-GW (See Tables 2 and 3, pages 27 and 28, respectively). The bursting strength of the PD sheets was 20% higher than the CD sheets. The breaking length of the PD sheets was 44% higher than the CD sheets. A 25% increase in percent elongation was obtained from press drying. Press drying the handsheets resulted in a 25.5% decrease in tear strength. The stiffness of the CD sheets was 122% greater than the PD sheets. Again, this increase in Taber stiffness is a result of the higher caliper of the CD sheets than the PD sheets, 17.4 and 12.3 points, respectively. There was essentially no difference in ring crush between the PD and CD sheets, 126 and 127 lbs, respectively.

Although there was no basis for comparison between the NBD-GW and the newsprint-GW, it was seen that press drying still had the same general effect on the properties of the handsheets. That is, the PD sheets had higher bursting strength, breaking length, and percent elongation. Press drying was again found to decrease tear strength.

CONCLUSIONS

It is apparent from this study that the type of fiber does influence the properties of handsheets made by press drying. The same can be stated about conventionally dried sheets. The press dried handsheets had a lower equilibrium moisture content, higher burst factor, and higher tear factor as the amount of corrugated stock increased. The grade mix had no effect on the stiffness or caliper of the press dried sheets. The data for breaking length, elongation, and ring crush for the press dried sheets was erratic and no trends could be seen. Burst factor, elongation, and tear factor increased with increasing corrugated material for the conventionally dried sheets. The caliper and stiffness decreased with increasing corrugated content. A change in grade mix resulted in no change in breaking length or ring crush for the conventionally dried handsheets.

The breaking length and burst factor of the press dried sheets were higher than the conventionally dried sheets. The press dried sheets had lower stiffness and tear strength than the conventional dried sheets. The elongation and ring crush tests were too erratic to see any trends. The caliper of the conventionally dried handsheets was higher than the press dried sheets.

CONCLUDING REMARKS

The laboratory static press is a new addition to the facilities in the Department of Paper Science and Engineering here at Western Michigan University, so this study represents the first time the press was used for research. Consistent and satisfactory results were obtained thus indicating that press drying research can be successfully pursued here.

One other known study on press drying has been completed in this department and is entitled "THE EFFECT OF PRESSDRYING ON BOGUS MEDIUM," by Judith Lynn Reams (submitted July 28, 1982). However, a static press was not used in this investigation. A loaded drying fabric was utilized to simulate press drying

RECOMMENDATIONS

As mentioned earlier in this report, it is highly recommended for anyone desiring to pursue the topic of press drying to utilize a method which would minimize the wire pattern developed in the handsheets due to the knuckles of the wires. It has been suggested that these knuckles develop internal spot-bonds in the handsheets, and these bonds should not be neglected when comparing results with other methods of drying (12).

It is felt that the following list may provide interesting topics for future study:

1. Develop or utilize a method which would minimize the extensive wire pattern developed in the handsheets during this study using 150-mesh screens.

2. Compare press dried handsheets made from never-been-dried pulps to press dried handsheets made from dried paper that has been fiberized in a hydropulper.

3. Examine other characteristics of press dried sheets such as smoothness, porosity, water drop, and wet tensile strength.

4. Determine the effect of using an internal size, external size, or coating on press dried paper properties or characteristics.

5. Examine the recycleability of press dried sheets. This would become inportant if press drying becomes a commercial process.

LITERATURE CITED

1. Setterholm, V.C., Benson, R.E., Wichmann, J.F., and Auchter, R.J., USDA, For. Serv. Res. Pap. FPL 256, For. Prod. Lab., Madison, Wis., 1975.

2. Setterholm, V.C., Ince, P.J., Reprinted from Southern Lumberman, December 15, 1980.

3. Larson, R.G., A news release from the FPL, "Press Drying-A New Way To Make Paper From Hardwoods," FPL, Madison, Wis. (August 1980).

4. Engineering Section of Chemical Week, "A cheaper process for making better paper," September 23, 1981.

5. Cody, H.M., Pulp & Paper, 55(4): 100-102 (April 1981).

6. Paper Technology and Industry, 22(3): 90-91 (April 2981).

7. Attwood, B.W., Paper Technology and Industry, 22(3): 92-98 (April 1981).

8. Ince, P.J., TAPPI, 64(4): 107-109 (April 1981).

9. Setterholm, V.C., TAPPI, 62(3): 45-46 (March 1979).

10. Setterholm, V.C., Benson, USDA, For. Serv. Res. Pap. FPL295, For. Pro. Lab., Madison, Wis., 1977.

11. Byrd, V.L., USDA, For. Serv. Res. Pap. FPL338, For. Pro. Lab., Madison, Wis., 1979.

12. Michell, A.J., Seth, R.S., and Page, D.H., "The Effect Of Press-Drying On Paper Structure," 1983 International Paper Physics Conference, TAPPI Proceedings: 137-144.

13. Gunderson, D.E., "Temperature and restraint variables in continuous and intermittent Press Drying," 1983 International Paper Physics Conference, TAPPI Proceedings: 145-154.

14. Setterholm, V.C., Woodland Management, 2(4): 4 (Oct. 1981).

15. Wegner, T.H., Rosenthal, M.R., Southern Pulp and Paper, 45(4): 26-29 (April 1982).

16. Law, K.N., and Koran, Z., APPITA, 34(5): 387-390 (March 1981).

17. Horn. R.A., TAPPI, 62(7): 77-80 (July 1979).

18. Byrd, V.L., TAPPI, 62(7): 81-84 (July 1979).

19. Horn, R.A., TAPPI, 64(10): 105-108 (Oct. 1981).