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The Effect of Wet Pressing on Filler Stratification

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THE EFFECT OF WET PRESSING

ON

FILLER STRATIFICATION

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ABSTRACT

Research was conducted to determine the effect of press loading upon filler stratification with the intention of observing the development of a stratified sheet.

Press conditions were held constant with the exception of pressure applied to the sheet. The sheet was then split and examined for filler content. The paper tested was highly refined, very moist, and of a heavy basis weight.

Results indicated a gradual trend of increased stratification with increased press loading. Filler moved toward the direction that water was leaving the sheet.

INTRODUCTION

Wet pressing is very important in the papermaking process. The primary function of wet pressing is to remove water from the sheet. However, the control and efficiency of the press section is important in controlling the sheets final properties.

Stratification in the wet press operation is a factor that affects the final properties of the paper web. If the sheet is stratified in the proper direction this phenomenon can be used to produce a more uniform sheet. The press simulator allows us to explore the effects of nip loading, nip residence time, and controlled water removal direction. If these factors are properly controlled then stratification may act to create a more uniform sheet.

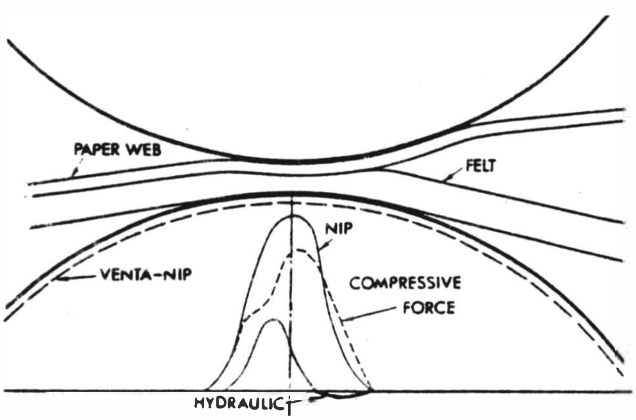
PRESSING OBJECTIVES

The primary purpose of wet pressing has been to remove as much moisture from the paper web as possible before it enters the dryer section while maintaining the quality of the sheet or improving it. An increase of one percent in consistency prior to entering the dryer section represents a nine percent savings in energy consumption within the dryer section. This represents a substantial cost savings.(1) The influence of the press section on sheet quality is becoming a subject of great interest. Sheet quality is a broad area in itself. It can include things such as strength, caliper, porosity, sheet defects, and two sidedness.(2)

In the past it has been thought that the quality of a sheet was made on the wire due to formation, fines and filler distribution, wire mark, and two sidedness. This line of thought is not entirely correct, although these factors definitely affect sheet quality it is possible to take an excellent sheet from the former and ruin the quality in the press section.(3) Some of the variables within the press section that affect paper quality will be discussed in the successive sections of this paper.

FACTORS AFFECTING WATER REMOVAL

It is important to have an understanding of the principles in the pressing process in order to understand the effect it has upon paper quality. Figure 1 shows the pressure machine direction distribution in a press nip. The total pressure increases on the ingoing side of the nip. The maximum total pressure is applied at mid nip and then declines on the outgoing side. The total nip pressure is made up of two components.



FigA. Press Nip Pressure Distribution

One component is the compressive pressure which is the pressure applied to the felt and fiber within the nip. The other component is the hydraulic pressure which is the pressure applied to the water within the nip.(2)

The sheet and felt entering the nip are subjected to increasing pressure which compacts their structure. This stage continues until all of the voids in the sheet are eliminated and the sheet has reached saturation. When saturation occurs hydraulic pressure starts. The hydraulic pressure builds toward mid-nip and water is forced from the web. The flow rate from the sheet decreases when approaching the center of the nip, and the compressive force continues to increase until maximum density is reached. The sheet expands in the outgoing portion of the nip and as it expands air and water are drawn back into the sheet by capillary forces created by the reformation of voids within the sheet. This flow reversal is indicated by the negative hydraulic pressure.

MacGregor said that pressing in its simplest form is water removal from the sheet by mechanically reducing the volume of the sheet. Water removal is directly related to densification and one cannot occur without the other.(4) The density of a sheet is directly related to the force applied to the sheet and the length of time that it is applied.

THE STRATIFICATION PROCESS

Sheet stratification is defined as the change in vertical distribution of sheet fiber and filler caused by fluid shear forces during the wet pressing process.(5) These forces in theory have components in all three directions (x,y,z) depending on the way that the water is forced to leave the fiber network. Fluid shear forces within the paper web are the result of dynamic interaction between the compression and permeability of the fiber network.(6) Any time that the mechanical forces holding the web together are not large enough to exceed the hydraulic shear forces within the sheet then fiber slippage can occur which causes stratification.

SHEET FURNISH

The sheet structure is defined as the internal distribution of fiber, fines, filler, and the surface characteristics of the sheet.(5) Wet pressing has a great influence upon the structure of the sheet. In addition to the densification and bonding that occurs during pressing another important influence to the process is the possible development of fluid shear forces discussed above. The most important thing that influences fluid shear forces is the sheet structure which is directly related to the furnish. Things that make water removal more difficult during pressing increase the chance of fluid shear force defects occurring.

Refining is a good illustration of a process that makes water removal more difficult. It creates fines, fibrillates the fibers, hydrates fiber, and delaminates fiber. These things make dewatering of the sheet more difficult and shear forces increase. The higher local velocities can cause movement of the structure creating stratification. Experimental work has indicated that highly refined, wetter, and heavier sheets are more susceptible to stratification.(6) For these reasons I have chosen a furnish that will be refined well. This will create fines and by making a heavier sheet stratification is more likely to occur.

WATER REMOVAL DIRECTION

Fines and fillers within the sheet are much smaller than the fibers in the web. Given the difference in size between these components, it is possible for the water that leaves the sheet surface in the press section to cause stratification and to carry these components with it. The vertical redistribution of the components depends upon the direction of water flow, force of the flow, and the structure of the sheet. Press section stratification densifies the sheet at the surface where the water is exiting. This densification reduces the pore size and the fines and fillers are filtered more easily.

Twin wire and top wire formers have produced sheets that are more uniform in fines and filler distribution than the Fourdrinier wire formers.(7) Fourdriniers produce sheets that are somewhat two-sided with the wire side having fewer fines and

fillers due to the effect of filtration. Work done by MacGregor (1) suggests that by preferentially removing the water in the press section from the side of the sheet that is lacking in fines will cause the fines and fillers that are moving with the water to act to densify the side that is lacking fines and filler. This will provide a more uniform sheet. If no fines or filler movement is desired then a longer nip residence time should be used to decrease the fluid shear forces that cause the movement of fines and filler.(5) The strategy given above can also be used to create more uniform surface characteristics. This would decrease the amount of fiber picking done by a smooth roll which is used to smooth the peaks on the surface. The control of water removal may serve to consolidate the loose surface rather than it being picked apart by the smooth roll.

PRESS SIMULATOR

The center piece of equipment that was used in this experiment is the wet press simulator. The simulator uses a simple weighted hammer with a drop mechanism and an anvil. The hammer can be weighted with differing amounts of weight to obtain different press loads. The hammer is released and slides down steel shafts to strike a felted handsheet resting on an anvil.

The anvil is composed of a steel plate that covers a force transducer. The force transducer provides a pressure pulse signal that can be sent to a storage oscilloscope. The oscilloscope stores the pressure pulse on the screen where it can

be recorded. The peak voltage is translated to pounds force applied to the sheet. The calibration curve is shown in Figure 1. Previous experiments indicate that the shape of the pressure pulse from the transducer is in good agreement with the conditions found in actual press nips.(8)

The press impulse for a conventional press is the linear load divided by the machine velocity. The press simulator has simulated conventional press conditions in a range of linear nip loads from 300 - 2000 pli and machine velocities of 600 - 1500 feet per minute.

BELOIT SHEET SPLITTER

The Beloit sheet splitter is constructed of two rotating rolls that form a nip. They are both chilled using freon. The wet web sample is passed through the nip and the portion of the sheet that contacts the chilled roll is frozen and sticks to the metal roll. In the outgoing portion of the nip the frozen sample is split into two parts. This procedure is repeated until the sample is split into the desired number of portions. Good operation of the splitter is dependent upon the speed and temperature of the rolls as well as the thickness of the sample sheet.

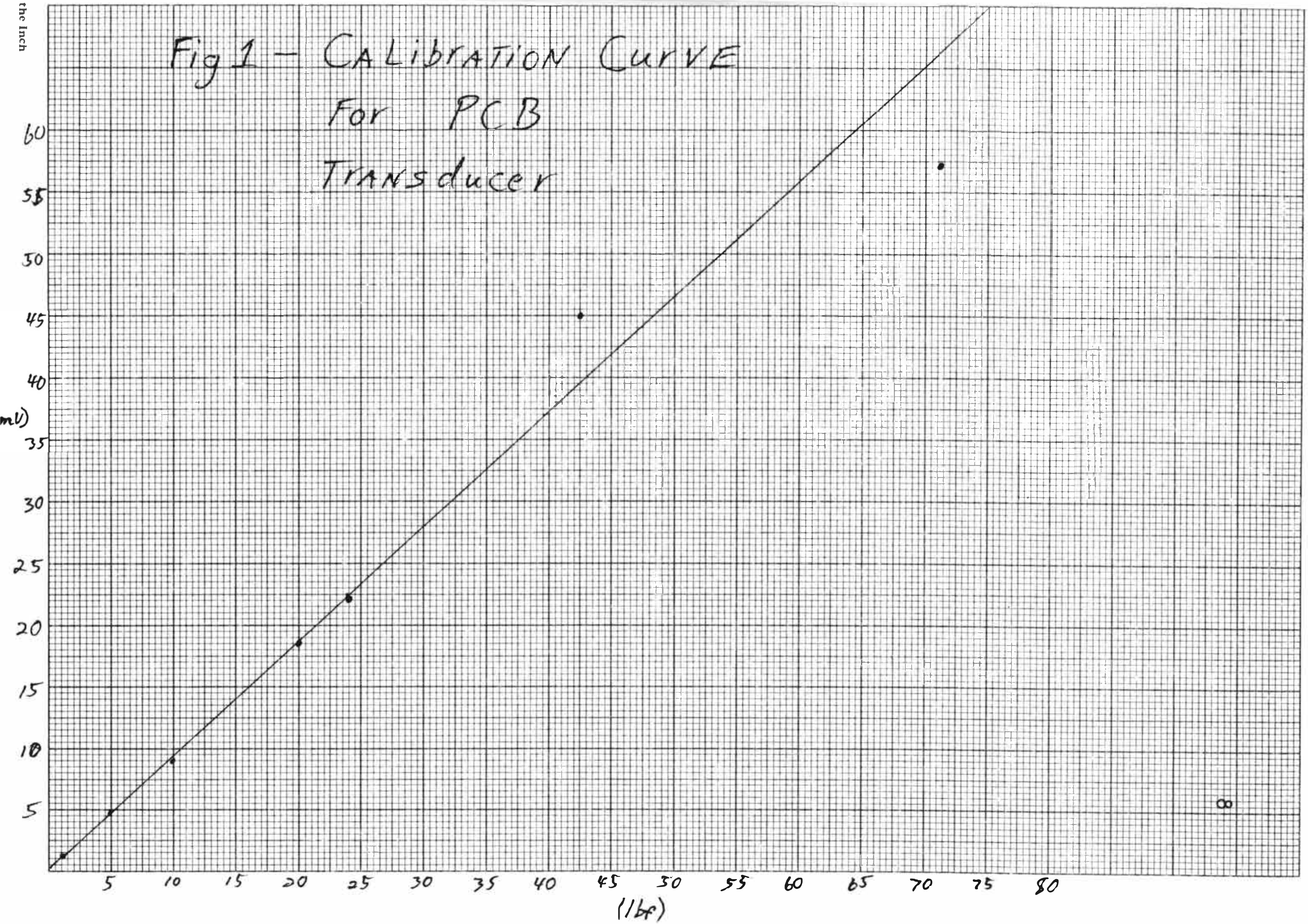


Fig 1 - CALibRATION Curve
For PCB
Transducer
60
55
50
45
40
mV)
35
30
25
20
15
10
5
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
(lbf)

PROCEDURE

The experimental procedure in this thesis involves making paper on the WMU pilot plant paper machine. The wet press simulator was used to determine the effect of pressure on stratification of fines and filler within the sample sheet.

FURNISH & HANDSHEETS

The furnish for this experiment was 100% northern softwood. The paper was made on the WMU pilot plant machine to provide a sample sheet that duplicates the sheet that would be entering an actual machine press. The stock was refined to a freeness value of 302 csf. The paper was made at a basis weight of 100 lb/3300 sqft. The machine speed was approximately 35 fpm. Target solids levels are 20% at the couch and 20-25% after the press. Machine alkalinity was at a pH of about 7.12. The stock had 20% calcium carbonate added. The paper was pressed lightly with the first press (4 psi) and removed from the machine before entering the dryer section. Handsheets were cut with a die and placed in individual ziplock bags which were refrigerated for storage.

FELTS

Felt samples were cut from a wet press felt with a die to fit the press simulator. The felt samples were oven dried to determine their dry weights then conditioned to 30% moisture for testing. This was done by adding the proper amount of moisture to the sample in a ziplock bag. Felt samples were rinsed with

distilled water and reconditioned following each use.

PRESSING

The felt and sheet samples were adjusted for proper moisture content by weight again just prior to pressing. This was done by adding water to the sample with a spray bottle as all the samples were below 30% CY. This method did not create any movement of filler because the amount of water added was so small and the mist application could not create any hydraulic forces that exceed the mechanical strength of the web. Felt and paper samples were placed in a configuration that preferentially removed water from the wire side of the sheet. Felt samples were suspended above the sample sheet. This separated the felt from the sample following the pressure pulse and reduced the amount of rewet. The test samples were put on the anvil and the hammer was dropped creating a pressure pulse measured by the force transducer. Five weight levels were used to press the samples.

After impact the felts and handsheets were placed into tared bags. They were weighed to determine the amount of moisture pressed from the sheet. The nip residence time was held constant at 3.5 ms.

ANALYSIS OF THE SHEET STRUCTURE

The pressed sheets were analyzed for the location of filler in the sheet. The Beloit sheet splitter was used to separate the sheet into two layers in the Z direction. The sheet splitting conditions were determined by trial and error. The initial samples for each different weight were split, dried, and ashed until the conditions were found that provided the same percentage of cellulose in both the wire side as well as the felt side samples. The rest of the samples under that weight were split using the same conditions. The splitting conditions are found in Appendix I. Each layer was dried to standard conditions and was then examined for filler content using a thermogravimetric analyzer. The analyzer heats the sample at a controlled rate and records the weight. The samples were heated from 25 deg. C to 800 deg. C. This range was used so that the cellulose would be incinerated leaving behind only the calcium carbonate.

RESULTS AND DISCUSSION

The overall test results are presented in table I and in fig. 2. Table I gives the pressing conditions and dewatering characteristics. Figure 2 compares the average percentage of filler in the samples for each of the five weights.

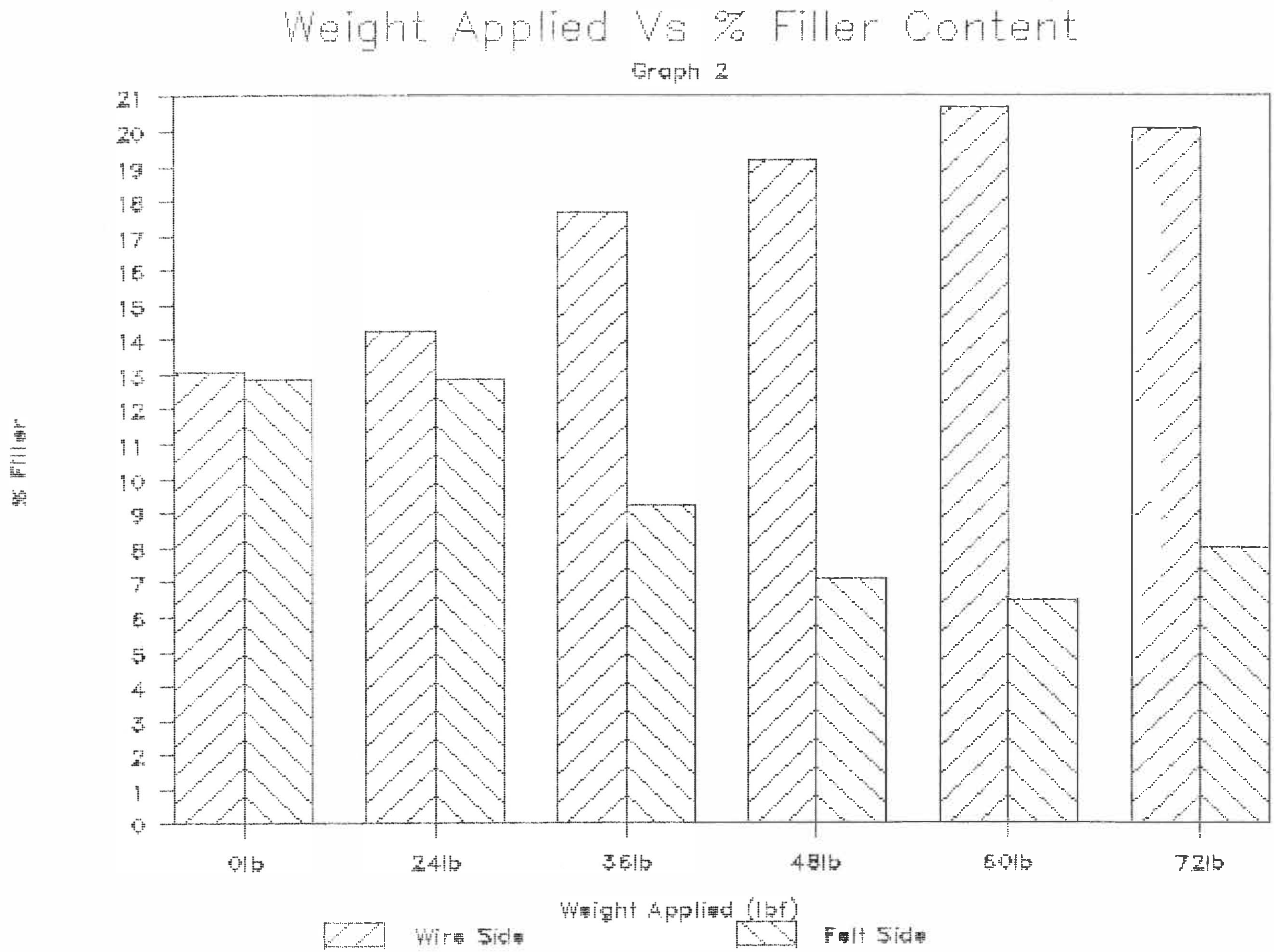

Weight Applied Vs % Filler Content
Graph 2
% Filler
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0lb
24lb
36lb
48lb
60lb
72lb
Weight Applied (lbf)
Wire Side
Felt Side

TABLE I - Pressing Data

wt (lb)	Avg %CY before pressing	Avg %CY after pressing	change in %CY	peak voltage	wt (lbf)	pressure (psi)
0	30.0	30.0	0.00	0.00	0.000	0.00
24	30.0	41.3	11.3	10.8	12300	4456
36	30.0	41.9	11.9	13.3	15100	5470
48	30.0	43.1	13.1	15.6	17500	6340
60	30.0	43.0	13.0	15.9	17900	6486
72	30.0	43.5	13.5	16.0	18100	6522

The data from table I indicates a linear relationship between dewatering and press loading with all other things remaining the same. The only discrepancy was noted in the relationship between the 48 lb and the 60 lb runs. The consistency did not increase in the 60 lb run. This may have been due to a change in ambient conditions or rewet from the press felt. The laboratory in which the press is located does not have a controlled atmosphere. Another possible source of error is the consistency of time taken to return the sample to its bag. Evaporation would change the weight of the sample slightly. The successive testing steps between pressing and getting the dry weight of the split samples is also a source of uncertainty. Despite the numerous sources of error the results for this portion of the experiment turned out as expected. Great care was taken to treat each sample identically.

The next phase of the experiment was to split the pressed samples. The Beloit sheet splitter was used to split the paper. This piece of equipment is very tricky. Many runs were made to find the conditions needed for each pressure level. The correct

settings were found by splitting the sheet under test conditions. The samples were then ashed and working backwards from the % filler it could be determined if the cellulose in each side of the split sheet had the same weight. Careful handling of the samples was mandatory for the split to turn out well.

Figure 2 indicates the average percentages of filler in the wire and felt sides for each of the five levels of pressure loading. The results indicate that this procedure has indeed stratified the filler within the sheet. The control run with zero loading indicates that the distribution of filler within the sheet coming off the paper machine is very uniform. The successive levels of pressure indicate a gradual increase in filler movement with the exception of the 72 lb pressure loading. This run indicates that the movement of filler had decreased from the previous run. The change from the general trend may be attributed to a error in calculation of the proper conditions for achieving equal portions of cellulose. It may also be caused by the general disruption of the sheet at high pressures and short residence times.

Each of the loaded pressure levels indicate a higher percentage of filler in the wire side of the sheet. The felts were placed so that water entering the felt passed through the wire side of the sheet.

CONCLUSIONS

From the results of the experiment it seems that while the possible sources of error are numerous the procedure does produce a stratified sheet. The results also indicate a linear relationship between press loading and dewatering of the web. Stratification of filler within the web increased substantially between the 24 lb load and the 36 lb load. This could indicate the movement of filler due to dramatically increased shear forces within the web which exceed the mechanical forces within the sheet. A general trend of increasing stratification with increased press loading was noted with all other remaining the same until high loading was reached.

The higher percentage of filler in the wire side of the sheet supports the theory that filler and fines collect toward the surface where water is exiting. The samples were felted on one side only.

RECOMMENDATIONS

For further use of this procedure it is recommended that the press simulator be moved to a lab with a controlled atmosphere. Due to the great variability involved with the beloit sheet splitter it is recommended that a different method be used to split the paper web. With these changes this stratification procedure may be used to study the following areas:

1 The effects of furnish on stratification.

2 The effects of refining on stratification.

3 The effects of stratification on surface and printing properties.

4 The effects of stratification on drying rates due to closed surfaces.

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APPENDIX I - Final Trial & Error Sheet Splitting Conditions

Wt (lb)	Roll Speed (rpm)	Temp (F) W	Temp (F) F	Wt of split Samples(g) W	Wt of split Samples(g) F	Oven Dry Wt (g) W	Oven Dry Wt (g) F	% Fiber W	% Fiber F	% Filler W	% Filler F
0	25	16	16	3.33	3.21	0.46	0.42	86.90	87.10	13.10	12.90
24	25	20	16	2.48	2.31	0.46	0.41	85.60	87.20	14.40	12.80
36	20	20	16	2.61	2.53	0.47	0.39	82.60	90.80	17.40	9.20
48	15	20	16	2.52	2.43	0.44	0.35	80.80	92.70	19.20	7.30
60	10	20	16	2.63	2.37	0.56	0.30	78.90	93.90	21.10	6.10
72	10	20	16	2.64	2.42	0.56	0.34	80.00	92.00	20.00	8.00

W = Wire Side Sample
F = Felt Side Sample