INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

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A COMPARISON OF IMPULSE DRYING TO DOUBLE FELTED PRESSING ON PILOT-SCALE SHOE PRESSES AND ROLL PRESSES

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SUMMARY

Pilot-scale shoe press and roll press experiments have been conducted to compare impulse drying and double felted pressing. Both ceramic coated and Beloit Type C press rolls have been evaluated.

The experiments show that impulse drying can provide significantly higher outgoing solids than double felted pressing at the same impulse. For example, at an impulse of 0.234 MPa seconds (34 psi seconds), sheets at an ingoing solids of 52% were impulse dried (using the Beloit Type C press roll) to 68% solids while optimized double felted pressing could only yield press dryness of, at most, 60%.

When the sheets of this study were conventionally pressed to 52% solids and dried they exhibited a geometric mean STFI compression index of 25.9 N m/g and a mean Burst index of 3.0 kPa m^2/g. Similar sheets, pressed from 52% to 60% solids in a double felted extended nip press exhibited an increase in STFI Index of 19.6% and an increase in Burst index of 40%. Sheets impulse dried from 52% solids to 68% solids yielded additional STFI and Burst index increases, over double felted pressing, of 3% and 17% respectively. Hence, impulse drying can be expected to yield substantial press dryness advantages with a small physical property improvement over double felted pressing.

Impulse drying with the ceramic coated roll on the Beloit shoe press yielded outgoing solids and sheet physical properties that were marginally superior to double felted pressing at the same impulse. The extent to which inaccurate grinding and sheet sticking lead to this result needs further investigation.

The experiments demonstrated that both the ceramic coated roll and the Beloit Roll C could be effectively and safely heated using induction heating and that press felts could survive roll contact even at roll temperatures as high as 315°C.

The experiments identified press roll to sheet sticking as an important issue that needs to be more fully explored. To assess potential sheet sticking problems, an apparatus must simulate three force components; the force of adhesion between the sheet and the press roll, the force of adhesion between the sheet and the felt and the draw force with which the sheet is pulled from the felt and/or press roll. In the handsheet experiments, reported in the shoe press phase of this study, only the first two of these forces were applied to the sheet. As sticking was consistently observed, research emphasis needs to be placed on evaluating roll sticking in a realistic environment for various combinations of press roll surfaces and felt.

State-of-the-art linerboard paper machines configured with a double felted ENP at the third press provide dryness of 48% at the entrance to the cylinder dryers. Typically, these machines may be used to manufacture 205 gsm linerboard having a CD STFI compression strength index of 21 N·m/g. From the limited experiments presented in this report, a fourth press configured with a 20" shoe and operated at 34 psi seconds impulse could substantially improve the dryness entering the cylinder dryers and result in substantial sheet strength improvements. The results of this study suggest that the sheet compression strength improvement can be achieved by either double felting the fourth press or by operating it in an impulse drying mode. The present data suggests that the major advantage of impulse drying is a substantial increase in dryness over what can be achieved by double felted pressing. Hence, the present experiments suggest that the potential for productivity improvement must be the major driving force for implementation of impulse drying technology for linerboard grades.

OVERVIEW AND OBJECTIVES

Ongoing laboratory and pilot scale research at the Institute of Paper Science and Technology (IPST) has demonstrated that heavy weight grades of paper, such as linerboard, can be successfully impulse dried[1-14] . That research has shown that deleterious sheet delamination can be avoided by a combination of processing strategies. These strategies include steps to make the pre-pressed sheets highly permeable to water flow and steps to reduce excess heat transfer to the sheet that results in excessive internal flash evaporation at the exit of the impulse dryer.

Research at IPST suggests that high sheet darcian permeability (low hydrodynamic specific surface) can be obtained by limiting refining to the minimum required for product aesthetics and by pre-pressing the sheet to as high a solids as possible. In addition, IPST research suggest that excessive pressure dependent heat transfer can be eliminated by using press roll surfaces composed of materials having low thermal conductivity, low heat capacity , and low density.

Previous IPST research has relied on both laboratory-scale and pilot-scale equipment that simulates impulse drying using a haversine pressure pulse characteristic of roll presses. Laboratory-scale experiments simulated impulse drying by using fast response hydraulics to simulate the load and thermal environment of impulse drying. A drawback of this work was that the in-plane wave like structure of the pressure pulse can not be duplicated in a one dimensional apparatus. In addition, sheets could not be rapidly removed from the felts at nip opening to reflect the actual process. To correct these deficiencies, low speed pilot roll press experiments were run to provide a wave like pressure-time history and to rapidly strip the sheet from the felt at the end of the process. While the combination of these experiments can be used to show direction, they fall short in that they limit the pressure-time history to a haversine.

A further limitation of previous experiments was that while impulse drying could be directly compared to single felted pressing, it could not be compared to double felted pressing. Because double felted pressing is considered the most effective pressing process such a comparison is of importance.

The primary purpose of the present research was to compare impulse drying to double felted pressing, where both are carried out on the same piece of equipment using identical pressure-time histories. Secondary objectives were to explore the influence of pressure pulse shape and press load on impulse drying and double felted pressing performance. Due to various problems encountered during the experiments, press surfaces having both low and high thermal properties were evaluated, while each was evaluated on both roll and shoe presses to determine if the results from roll presses can be directly scaled to shoe presses.

EXPERIMENTAL PLANS AND PROCEDURES

To assure a complete double felted database, two different Beloit pilot presses were operated in the double felted configuration and compared.

The shoe press experiments, conducted at Beloit, also suffer from an inability to properly simulate the real process. The most important of these is that a grade as heavy as 42 pound liner can not be continuously formed and fed to the pilot shoe presses. Therefore, the present experiments were conducted in a sheet fed mode. This resulted in a number of difficulties in that no tension could be applied to the sheet as it exited the nip and as the roll could not be raised it was heated while in contact with the moist press felt . This later effect resulted in excessive buildup of scale on both press roll surfaces and may have resulted in sticking. The shoe press results with the ceramic coated roll were further compounded by the fact that the roll was improperly ground such that one side exhibited excessive porosity and the entire roll was excessively rough.

Tables 1 and 2 shows the original experimental plan while Tables 3, through 7 shows the experimental plan that was actually executed. The main reasons for deviating from the initial plan was the perception, during the experiment, that the excessive sticking on the ceramic roll was due to an inability to remove calcium carbonate scale from the roll by doctoring with a polymer composite doctor blade. To rectify this problem the research team explored the effect of felt moisture and used a highly loaded bronze blade to try to remove the scale. Just after being installed, the bronze doctor blade overheated and gauged out a small area of the ceramic. Work using the ceramic roll was then halted as a safety precaution. It is at this point that the team decided to expand the work to include the Beloit Roll C and to examine a second felt at two levels of ingoing felt moisture.

Table 1. Original Plan for Double Felted Pressing Baseline Experiments
(Beloit X1 and X2 ENP, with Pre-Steaming)

Ingoing Solids, %	42									52								
Press Load, pli	4000			6000			8500			4000			6000			8500		
Pivot Position	-1	0	2	-1	0	2	-1	0	2	-1	0	2	-1	0	2	-1	0	2
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 2. Original Plan for Impulse Drying with the Ceramic Coated Roll
(Beloit X2 ENP, with Pre-Steaming)

Ingoing Solids,%	42									52								
Press Load, pli	4000			6000			8500			4000			6000			8500		
Pivot Position	-1	0	2	-1	0	2	-1	0	2	-1	0	2	-1	0	2	-1	0	2
148°C Roll Temp	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
204°C Roll Temp	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
260°C Roll Temp	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
315°C Roll Temp	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
371°C Roll Temp	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 3. Actual Experiment for Double Felted Pressing Baseline Experiment
(Beloit X1 ENP, with Pre-steaming, Nylon Felt, Low Felt Moisture)

Ingoing Solids,%	42												52											
Press Load, pli	4000			6000			7300			8500			4000			6000			7300			8500		
Pivot Position	-1	0	2	-1	0	2	-1	0	2	-1	0	2	-1	0	2	-1	0	2	-1	0	2	-1	0	2
	x	x	x	x	x	x			x	x	x		x	x	x	x	x	x			x	x	x	

Table 4. Actual Experiment for Double Felted Pressing Baseline Experiments
(Beloit X2 ENP, with Pre-steaming)

Ingoing Solids,%	42								52							
Press Load, pli	6000 & 8500								6000 & 8500							
Felt Type	B				R								B			
Felt Moisture	L		H		L		H		L		H		L		H	
Pivot Position	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2
	x	x	x		x				x	x	x		x			

Table 5. Actual Experiment for Impulse Drying with the Ceramic Coated Roll
(Beloit X2 ENP, with Pre-steaming, Felt B, 0 Pivot)

Ingoing Solids,%	42						52					
Press Load, pli	4000		6000		8500		4000		6000		8500	
Felt Moisture	L	H	L	H	L	H	L	H	L	H	L	H
68°C Roll Temp	x		x		x		x		x		x	
148°C Roll Temp	x						x					
165°C Roll Temp									x			
179°C Roll Temp											x	
204°C Roll Temp	x		x		x		x		x		x	
260°C Roll Temp	x		x	x	x	x	x		x	x	x	x
315°C Roll Temp				x		x				x		x

Table 6. Actual Experiment for Impulse Drying with the Beloit Roll C
(Beloit X2 ENP, with Pre-steaming, 42% Solids Ingoing)

Ingoing Solids, %	42															
Pivot	0								+2							
Felt Type	R				B				R				B			
Press Load, pli	6000		8500		6000		8500		6000		8500		6000		8500	
Felt Moisture	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
71°C Roll Temp			x				x						x		x	
148°C Roll Temp				x											x	
204°C Roll Temp			x	x			x						x		x	
232°C Roll Temp																
260°C Roll Temp							x								x	
315°C Roll Temp							x									

Table 7. Actual Experiment for Impulse Drying with the Beloit Roll C
(Beloit X2 ENP, with Pre-steaming, 52% Solids Ingoing)

Ingoing Solids, %	52															
Pivot	0								+2							
Felt Type	R				B				R				B			
Press Load, pli	6000		8500		6000		8500		6000		8500		6000		8500	
Felt Moisture	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H
71°C Roll Temp			x				x						x		x	
148°C Roll Temp				x												
204°C Roll Temp			x	x			x						x		x	
232°C Roll Temp							x									
260°C Roll Temp							x								x	
315°C Roll Temp							x									

In addition to the shoe press experiments, comparative roll press experiments were performed with a ceramic coated roll at IPST and with a Beloit Type C roll at Beloit. The Beloit roll press was operated in the sheet fed mode while the IPST roll press was operated in a batch continuous mode. Table 8 shows the experimental conditions investigated in these roll press experiments. For both roll presses, paper was pre-steamed to about 90°C prior to impulse drying.

Table 8. Roll Press Impulse Drying Experimental Conditions

Ingoing Solids,%	42			52	
Roll Press Roll Identity	IPST Pilot Ceramic Coated Roll		Beloit HRP Roll C	IPST Pilot Ceramic Coated Roll	
Press Load, pli	315	472	530	315	472
Speed, fpm	100	100	78	100	100
Impulse,psi sec	16	24	34	16	24
Felt Moisture	Low	Low	Low	Low	Low
71°C Roll Temp			x		
105°C Roll Temp	x	x		x	x
150°C Roll Temp	x	x		x	x
160°C Roll Temp			x		
200°C Roll Temp	x	x		x	x
210°C Roll Temp			x		
250°C Roll Temp	x	x		x	x
266°C Roll Temp			x		
300°C Roll Temp	x	x		x	x
315°C Roll Temp			x		
350°C Roll Temp	x	x		x	x
400°C Roll Temp	x			x	

The sheets to be impulse dried in these experiments were a Southern pine virgin Kraft, cooked to a Kappa number of approximately 100 and minimally refined to a Canadian Standard freeness of 720-760 ml. The furnish, designated Furnish #2 was found to contain 95+% Southern yellow pine with 5-% hardwood composed of gum, yellow poplar and oak.

Sheets were formed on the IPST low speed web former at 205 gsm basis weight. All of the paper was pressed to 42% solids on the IPST roll press. A few rolls of wet paper were pressed for a second time on the IPST roll press to achieve 52% solids. The weight weighed fiber length in samples of the linerboard was 3.7 mm while the fiber width was between 36 and 37 microns. Fiber perimeter was from 85 to 86 microns while fiber coarseness was from 33 to 35 mg/100m.

Rolls of 42% and 52% paper were impulse dried on the IPST pilot roll press. The remaining rolls of 42% solids paper were cut into 12" MD x 11" CD hand sheets and sent to Beloit. At Beloit these sheets were randomized, and half were pre-steamed and pressed on the X1 double felted press, at 16 psi sec, to 52% solids.

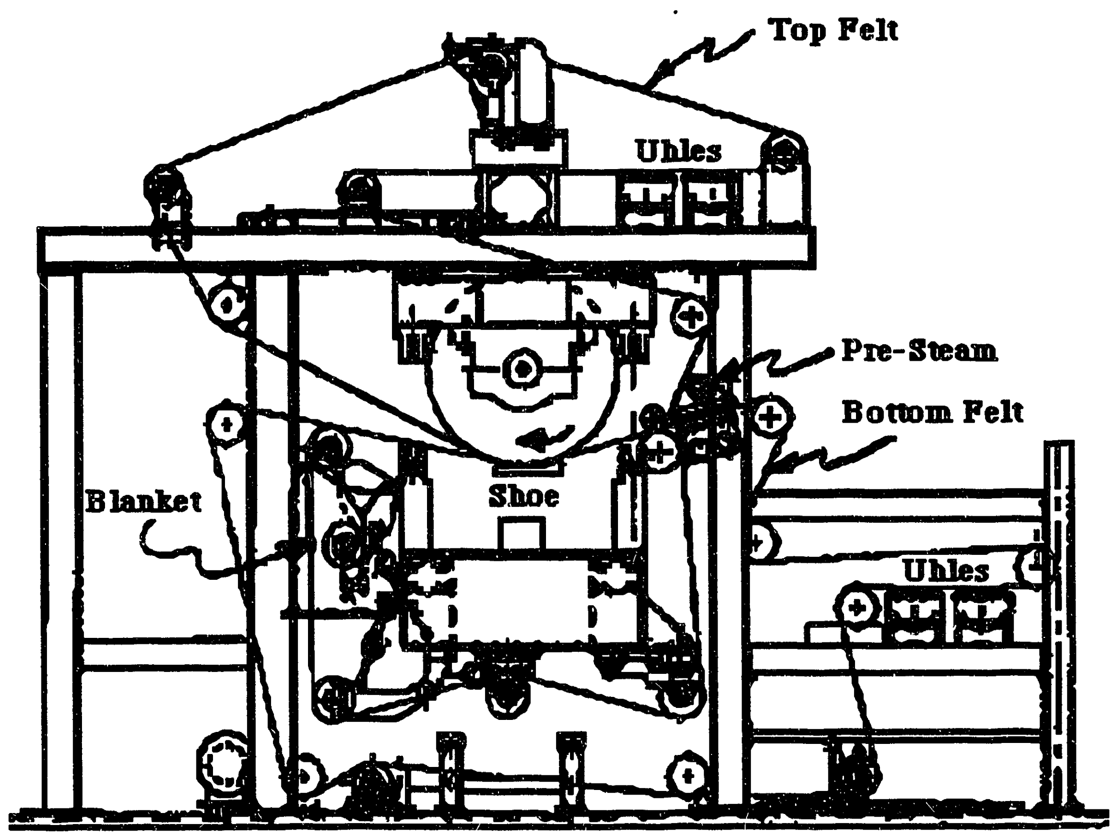
All Shoe press experimental conditions were replicated using five handsheets. Roll press experiments consisted of only one replicate at each condition.

Double felted pressed or impulse dried handsheets were cylinder dried and then oven dried, to determine outgoing solids and grammage, prior to undergoing conditioning and physical testing. In contrast, rolls of paper that were impulse dried on the IPST pilot press were cylinder dried, conditioned and tested before being oven dried to determine grammage.

The number and identity of tests per replicate are shown in Table 9.

Table 9. Description of Physical Testing

Physical Tests	Shoe Press Experiments		Roll Press Experiments	
	DF Pressing tests/sample	Imp. Drying tests/sample	DF Pressing tests/sample	Imp. Drying tests/sample
Z-Dir. Ultrasound (MD)	none	10	none	30
Z-Dir. Ultrasound (CD)	none	10	none	30
MD STFI Compression	10	10	10	30
CD STFI Compression	10	10	10	30
Burst Strength (Wire Side)	3	3	3	3
Burst Strength (Felt Side)	3	3	3	none
IPC Density	10	10	10	none

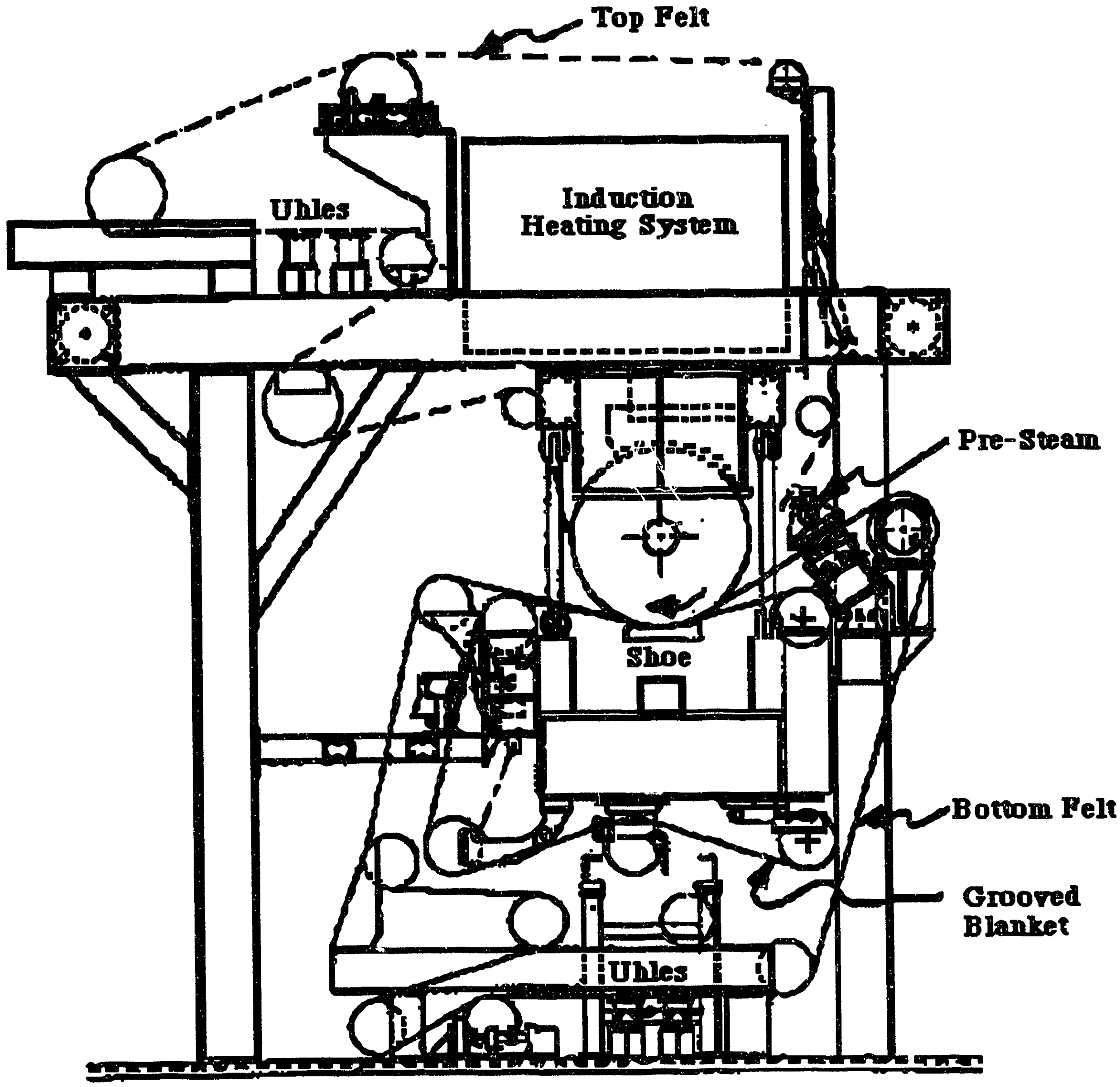


BELOIT PILOT SHOE PRESS X1

Figure 1. Schematic of the Beloit X1 Double Felted Shoe Press.

Figure 1 shows a schematic diagram of the Beloit X1 Shoe press as configured for double felted pressing. The X1 machine is a double felted extended nip pressing apparatus for sample handsheet evaluation trials at commercial operating conditions. The machine has pre-steaming capabilities for hot as well as wet pressing evaluation. The machine generally utilizes a top grooved roll. Felt conditioning and moisture are maintained within commercial limits by the uhle box vacuum and felt showering.

Figure 2 shows a schematic of the Beloit X2 Shoe press as configured for impulse drying or for double felted pressing (see dashed lines). The X2 machine is the second press of a continuous sheet demonstration pilot machine including a wet end former. The machine is capable of commercial operation for continuous sheet production at speeds of better than 5000 fpm. For the present experiments the press was operated separately from the wet end, in a handsheet mode. Handsheets were presteamed in a manner similar to that of the X1 experiment with the exception that the X2 steam vacuum box consisted of two one-inch vacuum slots. The X2 machine also differed in that a grooved blanket was used in place of a grooved top roll for venting.



BELOIT PILOT SHOE PRESS X2
(Configured For Double Felted Pressing Or Impulse Drying)

Figure 2. Schematic of the Beloit X2 Shoe Press.

As the X2 machine was used to directly compare double felted pressing and impulse drying, the bottom felt was of a heat resistant variety whereas the top felt was conventional. In the impulse drying mode, the top felt was removed and the induction heaters were moved into position to supply heat to the press roll. Both the ceramic and the Beloit Type C rolls were heated to high temperatures without incident.

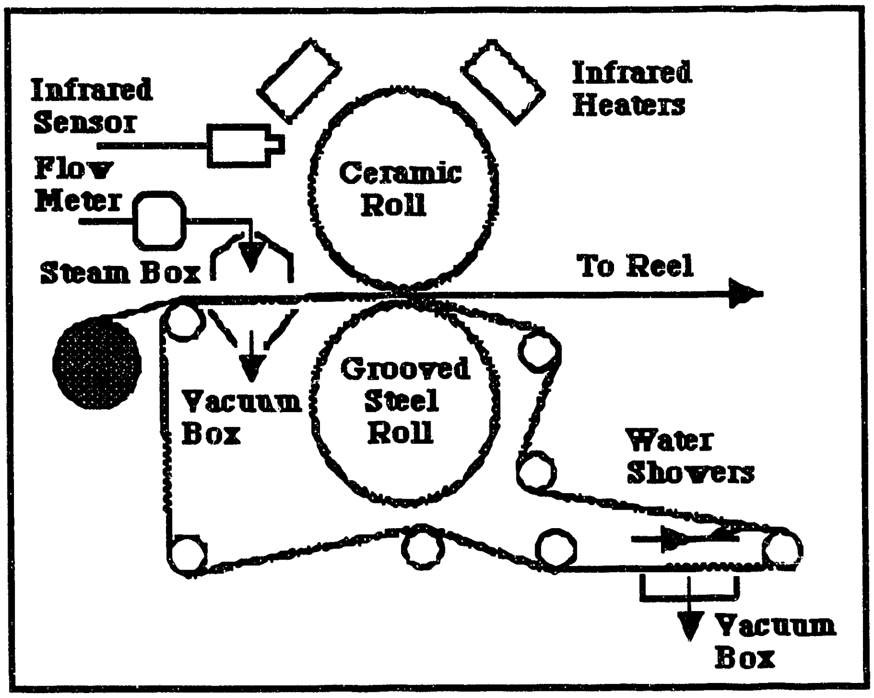


Figure 3. Schematic of the IPST Pilot Impulse Dryer Roll Press.

Figure 3 shows a schematic of the IPST pilot roll press that was operated in a batch continuous mode where rolls of pressed paper was impulse dried from 42 and 52% ingoing dryness at two different press loads. The IPST roll press was equipped with the same ceramic coated roll that has been described in earlier work (10-12). As in the previous work, the roll was heated by electrical infrared heating.

In order to test the concept of induction heating, the roll was also installed on the second nip of the IPST pilot roll press and heated by induction.

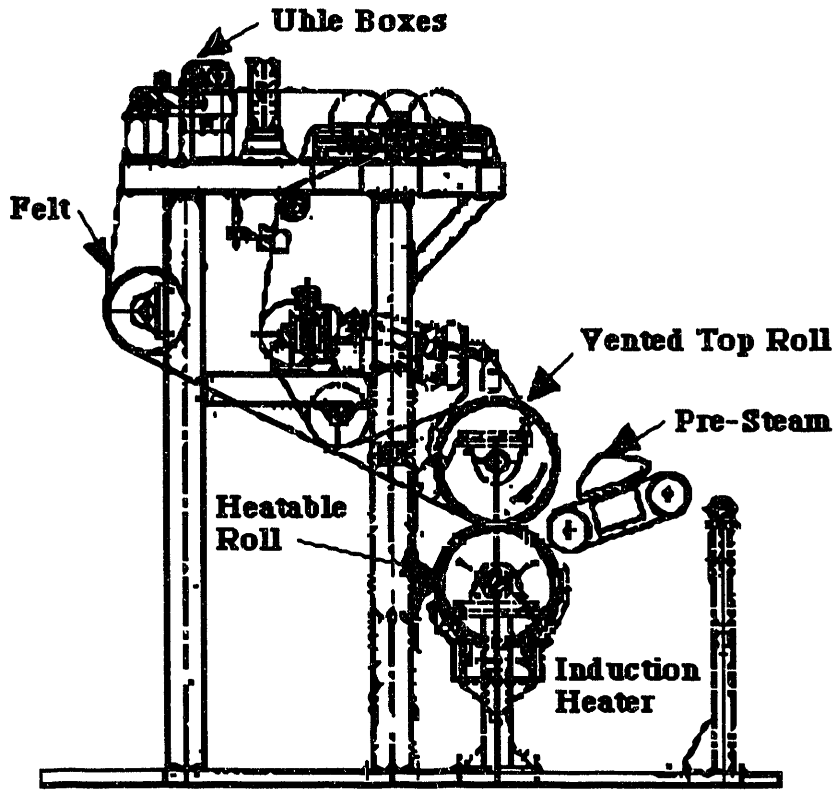


Figure 4. Schematic of the HRP Beloit Pilot Impulse Dryer Roll Press.

Figure 4 shows a schematic of the Beloit HRP roll press which was equipped with a newly surfaced Beloit Roll C. In the present research, the HRP was operated in a sheet fed mode to impulse dry handsheets that were pre-pressed to 42% solids.

The actual pressure profiles used during double felted pressing and impulse drying on the Beloit X1 and X2 shoe presses are considered proprietary to the Beloit Corporation. While the "-1" and "0" pressure profiles were very similar, the "+2" pivot resulted in more gradual compression to a much higher peak pressure as shown in Figures 5. Figure 6 shows the haversine pressure profile that were achieved during IPST and Beloit roll press impulse drying experiments. Roll press conditions were chosen such that the resulting press impulse would correspond to that obtained on the shoe presses. Shoe press loads of 4000, 6000, and 8500 pli correspond to 16, 24 and 34 psi seconds impulse respectively.

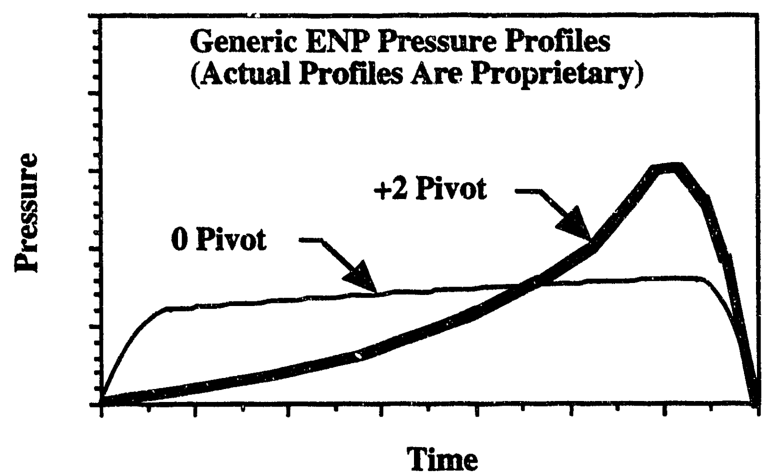


Figure 5. Generic Pressure Profiles for the Beloit Shoe Press set at the "0" and "+2" Pivot.

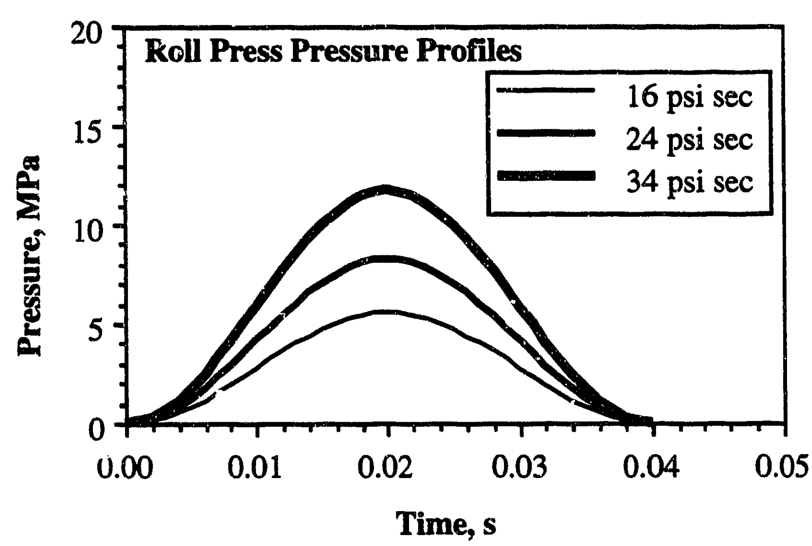


Figure 6. Pressure Profiles for the IPST and Beloit HRP Roll Presses.

RESULTS

The results are presented in four sub-sections covering; controls, double felted pressing, impulse drying, and the sheet sticking issue. In each, data will be presented in graphs and as regression equations to show dependency relative to process variables.

Controls:

Previous research (10,12) has shown that sheet permeability, as characterized by hydrodynamic specific surface, controls the critical roll temperature above which impulse drying leads to sheet delamination. Since one objective was to compare critical impulse drying temperatures from one press to another and from one roll to another, the variability of permeability needed to be kept to a minimum. To document the permeability, an equal number of samples, from each roll of paper, as pressed to 42% solids were tested for hydrodynamic specific surface. Table 10 shows the mean, coefficient of variation and number tested for basis weight, solids and specific surface. A mean hydrodynamic specific surface of 1.8 m^2/g was consistent with previous measurements (12) of this pulp as refined to a similar freeness. Regressions on the data showed that specific surface was a random variable being independent of small changes in basis weight, pressed solids and independent of the roll of paper from which the sample was taken.

Table 10. Hydrodynamic Specific Surface of Sheets Pressed to 42% Solids

	Basis Weight g/m^2	Solids, %	Specific Surface m^2/g
Mean	211.6	41.8	1.8
% C.V.	6.7	3.5	52.2
Number Tested	31	31	31

Figure 7 shows the distribution of specific surface found in the sample of 31 sheets.

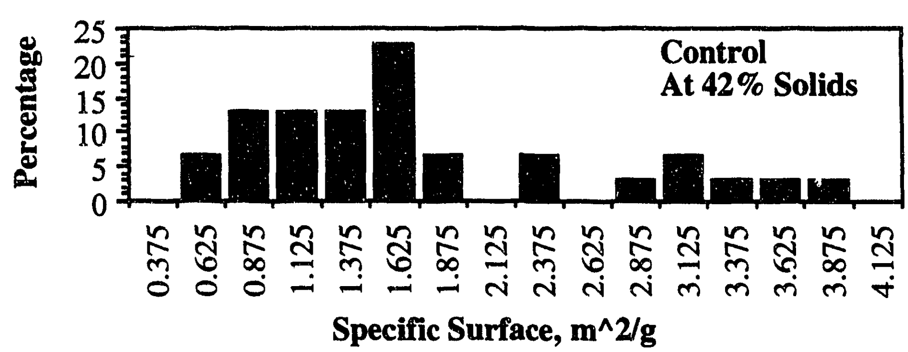


Figure 7. Hydrodynamic Specific Surface for 42% Solids Control.

An equal number of 12" x 11" sheets, taken from each roll of paper produced and pressed to 42% solids at IPST, were cylinder dried and oven dried at Beloit. These sixty samples were then conditioned and tested at IPST to determine a physical property control for the experiments of this study. Table 11 shows the results of these physical tests.

Table 11. Physical Test Results for 42% Solids Control

	Basis Weight g/m^2	Solids %	IPC Density g/cc	MD STFI Index N·m/g	CD STFI Index N·m/g	BURST Index (wire side) kPa·m^2/g	BURST Index (Felt Side) kPa·m^2/g
Mean	211.0	42.1	0.43	22.1	13.3	2.1	1.9
% C.V.	6.9	3.8	3.8	5.9	7.8	15.3	12.0
Number Tested	60	60	60	60	60	60	60

Figure 8 through 14 show the distributions of basis weight, pressed solids, IPC density, MD and CD STFI Index as well as Wire and Felt side Burst Index for these controls.

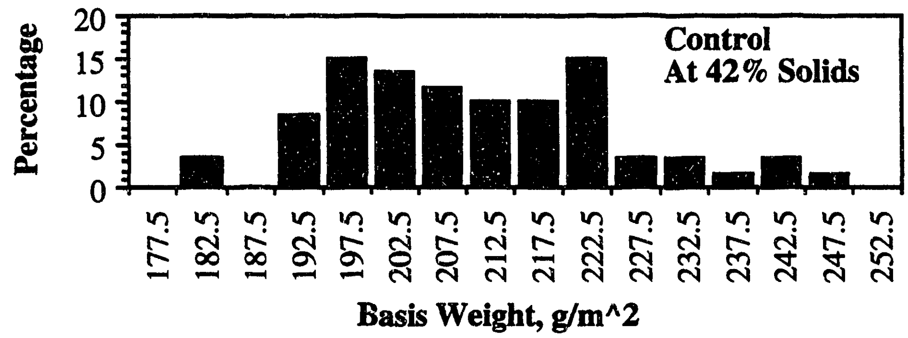


Figure 8. Basis Weight Histogram for 42% Solids Control.

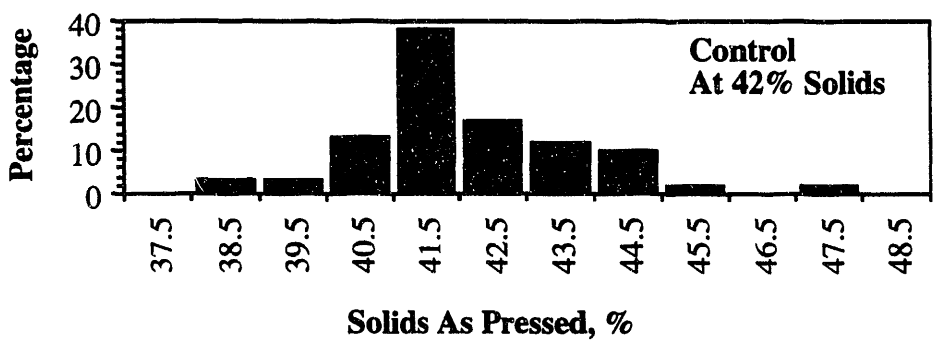


Figure 9. Pressed Solids Histogram for 42% Solids Control.

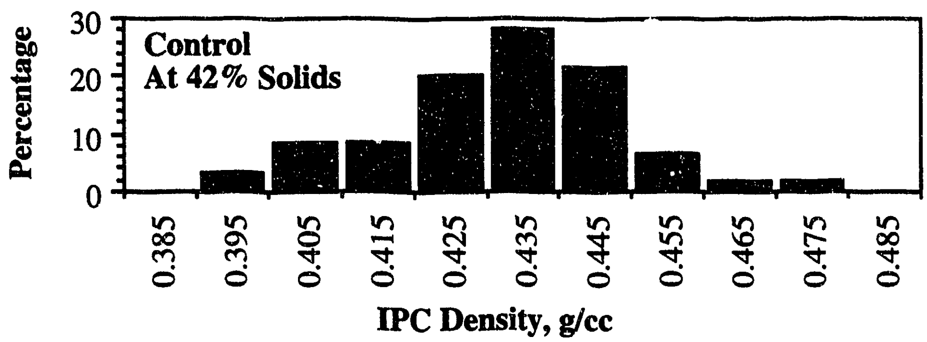


Figure 10. IPC Density Histogram for 42% Solids Control.

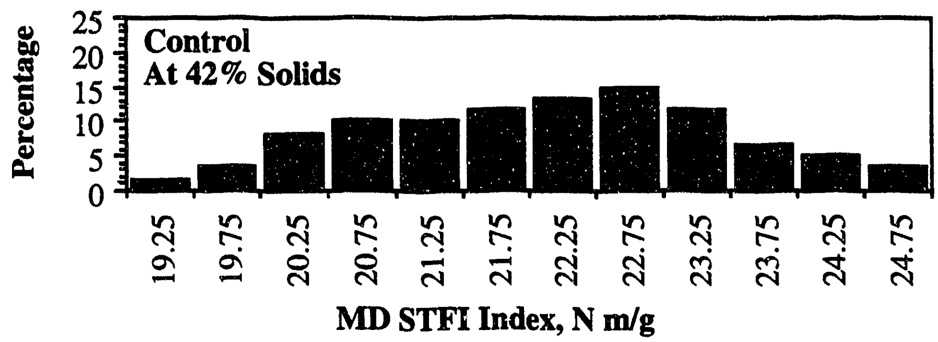


Figure 11. MD STFI Index Histogram for 42% Solids Control.

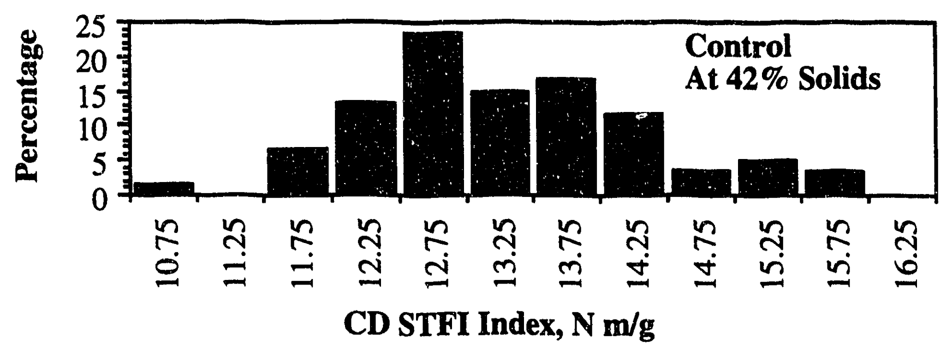


Figure 12. CD STFI Index Histogram for 42% Solids Control.

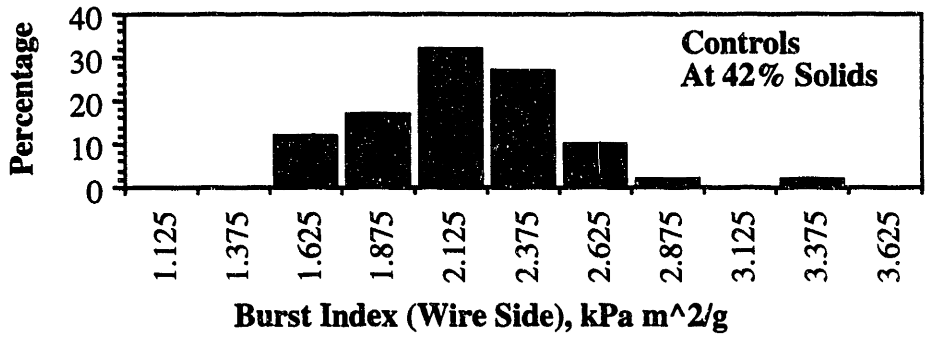


Figure 13. Wire Side Burst Index Histogram for 42% Solids Control.

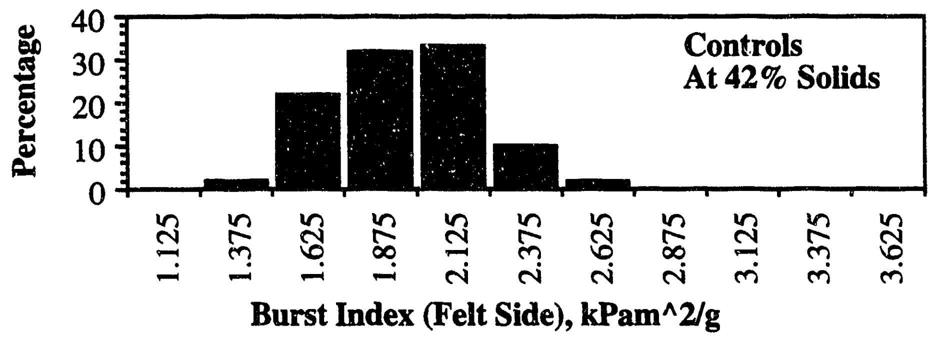


Figure 14. Felt Side Burst Index Histogram for 42% Solids Control.

Samples that were to be pressed or impulse dried from a starting dryness of 52% were pressed on the Beloit X1 double felted press. Sheets previously pressed to 42% solids at IPST were pressed to a nominal 52% solids with the press set at 4000 pli, "0" pivot at a speed of 1250 fpm (16 psi sec). Review of the raw data showed that, for the 264 sheets that were pressed to 52% solids before further pressing, their actual mean solids was 53.1 gsm with a coefficient of variation of 4 %. Five samples that were pressed to 52% solids, under these conditions, were cylinder and oven dried at Beloit and conditioned and tested at IPST. For these five samples, Table 12 lists the resulting mean physical properties.

Table 12. Physical Test Results for 52% Solids Control

	Basis Weight g/m2	Solids %	IPC Density g/cc	MD STFI Index N·m/g	CD STFI Index N·m/g	BURST Index (wire side) kPa·m2/g	BURST Index (Felt Side) kPa·m2/g
Mean	197.1	53.0	0.64	32.0	19.7	3.2	2.7

Double Felted Pressing:

Double felted pressing experiments were conducted on both the Beloit X1 and X2 Shoe presses. The Beloit X1 press was provided with standard nylon press felts and blanket. The designations on the top felt, bottom felt and blanket were, IA43+19200, IA43+19202 and YIEH0904 respectively.

Figure 15 and 16 show outgoing solids as a function of impulse. For these figures impulse in psi · seconds has been converted to MPa · seconds. The results clearly show the dryness advantage of operating at the +2 pivot position at press loads of 8500 pli. For the purpose of interpolation the following regression equation should prove useful.

%Sout = 45.039+32.214(Impulse)+0.117(%Sin)+0.909(Pivot)

Where:

%Sout is in percent.
Impulse is in MPa·sec.
%Sin is in percent
Pivot takes values of -1.0, 0.0, 2.0.

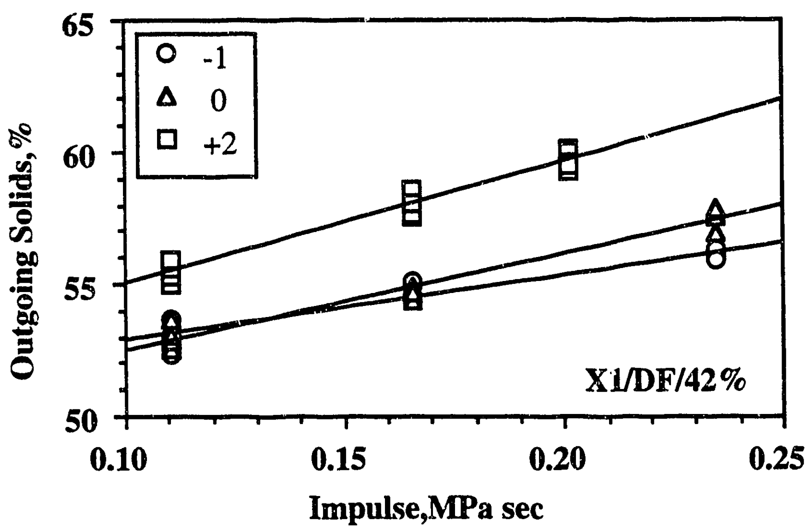


Figure 15. Outgoing Solids as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids Of 42%.

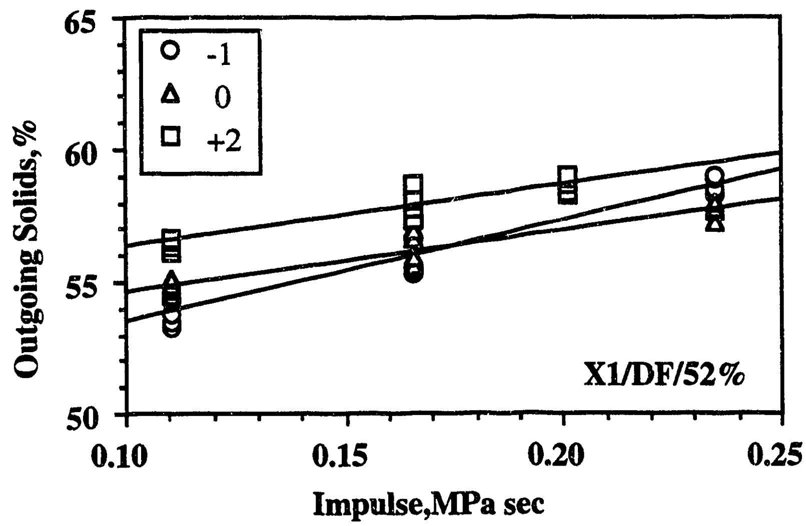


Figure 16. Outgoing Solids as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 52%.

After cylinder and oven drying, these sheets were conditioned and tested for their physical properties. Table 13 presents a regression that may be used to interpolate the various physical properties in terms of pressing conditions. The regressions are of the following form;

Property = A+B(Impulse)+C(%Sin)+D(Pivot)+E(Basis Weight)

Where:

Impulse is in MPa·sec.
%Sin is in percent
Pivot takes values of -1.0, 0.0, 2.0.
Basis Weight is in g/m^2

Table 13. Physical Properties Resulting from Double Felted Pressing on the Beloit X1 Shoe Press

Property	Units	A	B (Imp)	C (%Sin)	D (Pivot)	E (BWT)
IPC Density	g/cm^3	0.310	1.124	0.002	0.027	0.001
Burst Index (Wire Side)	$kPa{\cdot}m^2/g$	1.423	6.305	0.027	0.200	
Burst Index (Felt Side)	$kPa{\cdot}m^2/g$	1.978	8.368		0.194	
MD STFI Index	N·m/g	22.496	52.163	0.132	1.780	
CD STFI Index	N·m/g	2.217	44.332	0.175	0.886	0.030

Figures 17 through 26 show these properties as a function of impulse.

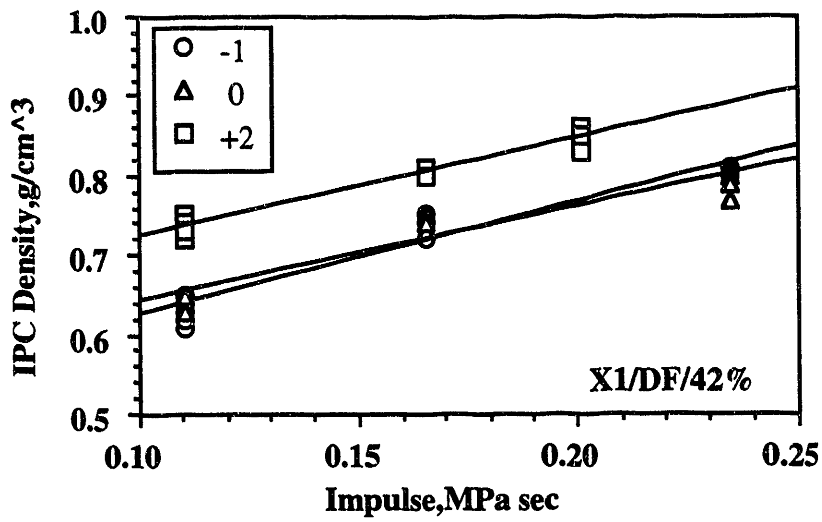


Figure 17. IPC Density as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 42%.

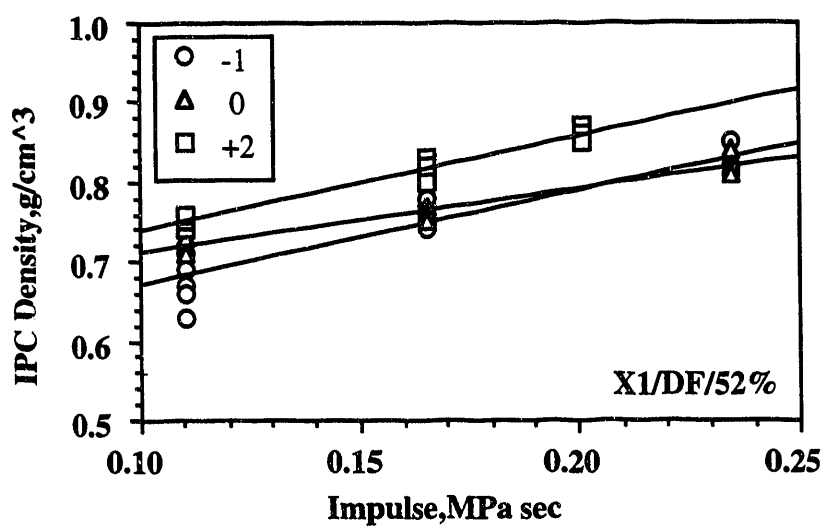


Figure 18. IPC Density as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 52%.

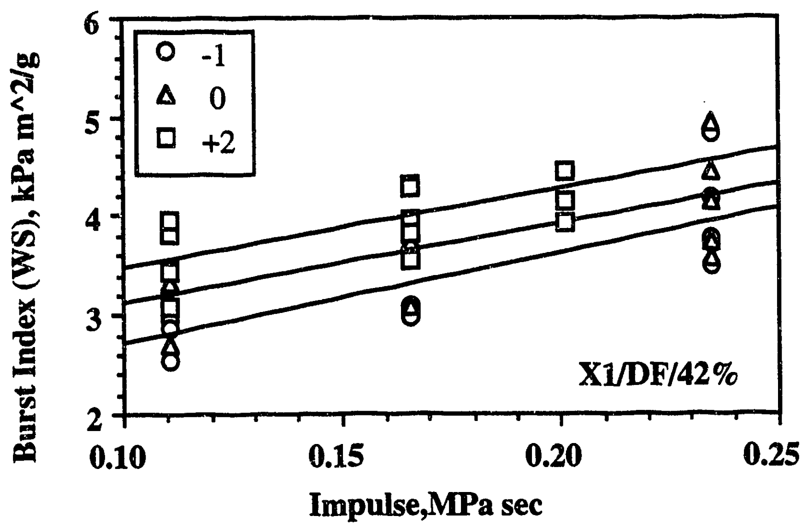


Figure 19. Wire Side Burst Index as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 42%.

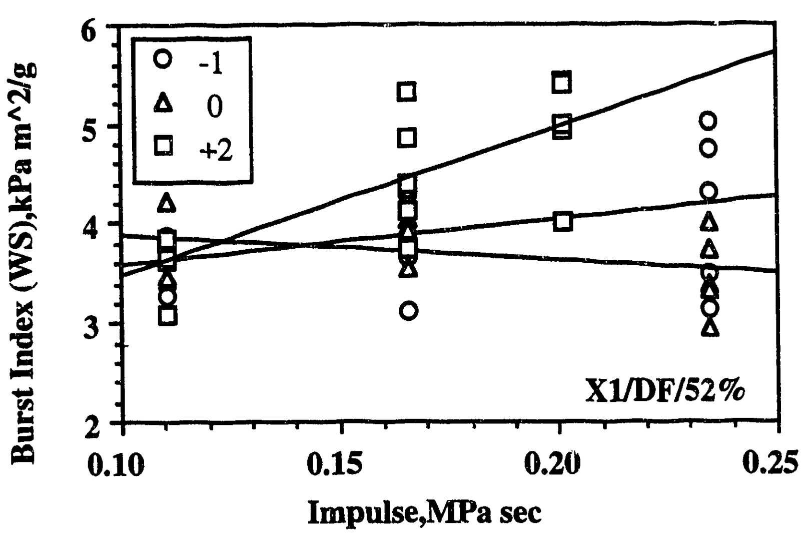


Figure 20. Wire Side Burst Index as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 52%.

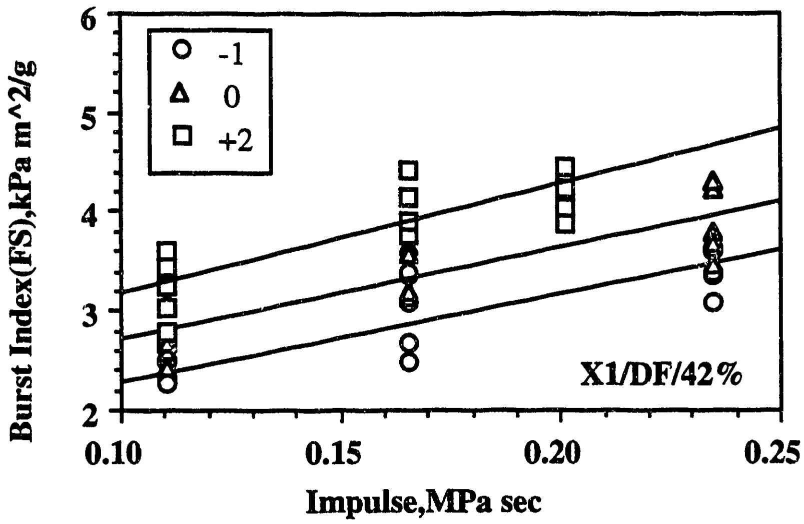


Figure 21. Felt Side Burst Index as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 42%.

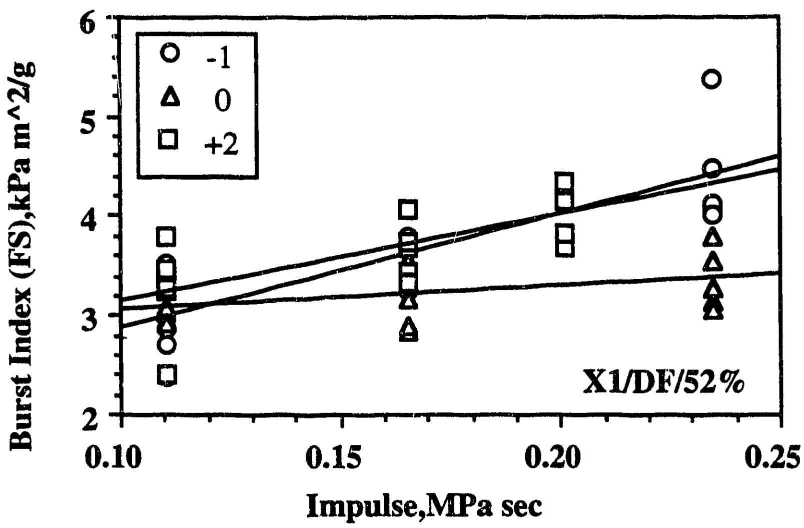


Figure 22. Felt Side Burst Index as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 52%.

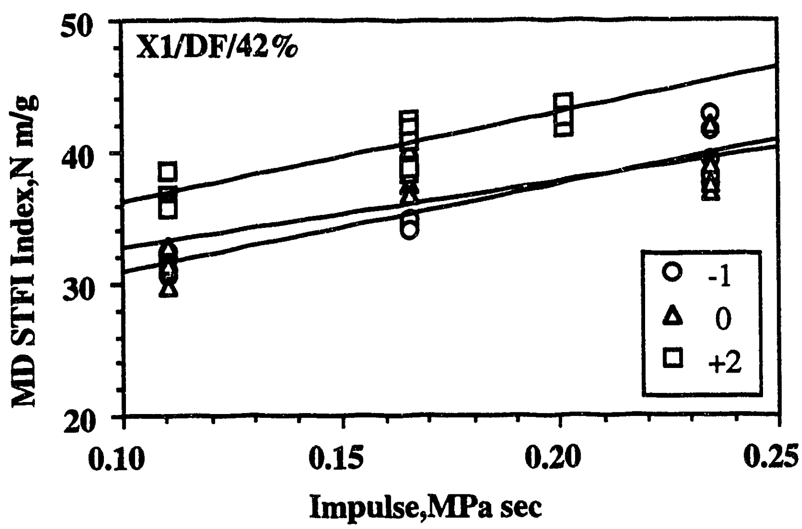


Figure 23. MD STFI Index as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 42%.

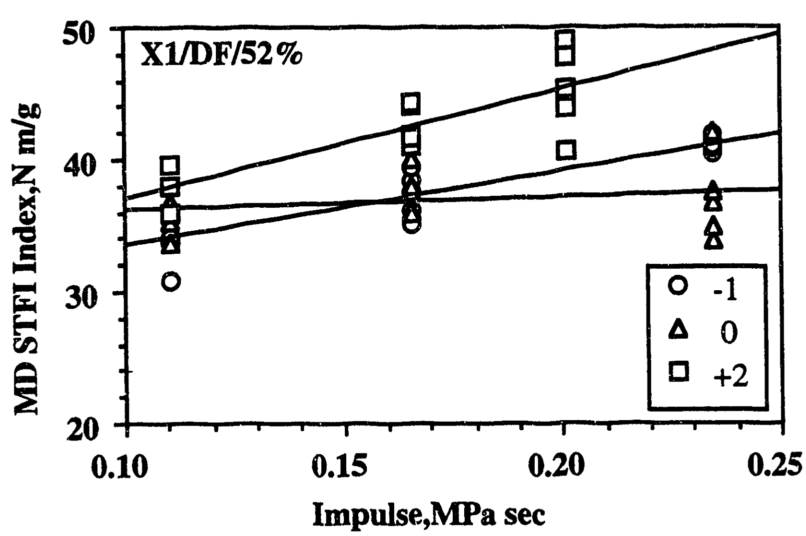


Figure 24. MD STFI Index as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 52%.

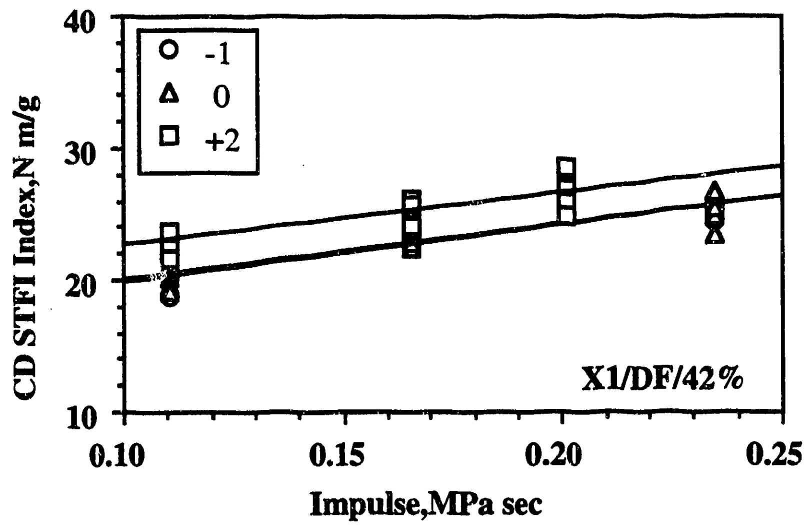


Figure 25. CD STFI Index as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 42%.

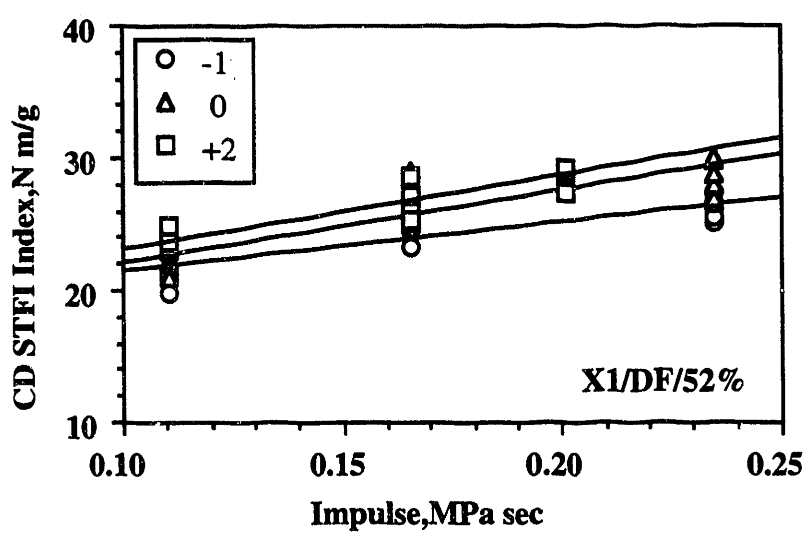


Figure 26. CD STFI Index as a Function of Impulse for Double Felted Pressing on the Beloit X1 Shoe Press from an Ingoing Solids of 52%.

In order to provide a direct comparison of double felted pressing to impulse drying on the same Shoe press and using the same felts, double felted pressing experiments were conducted on the Beloit X2 press. As with the X1 experiments, pre-steaming was used to increase ingoing sheet temperature. Because of design problems a less effective, smaller, vacuum box was used for the X2 machine. The double felted pressing experiments were performed after impulse drying with the ceramic roll which used felt B. Double felted pressing experiments were also conducted with felt R for comparison. Two different felt moistures were investigated, a low value at 25% ingoing felt moisture and a high value at 50% ingoing felt moisture (as measured by Albany Int/l staff). "0" and "+2" pivot positions and press loads of 6000 pli and 8500 pli were investigated.

Figure 27 and 28 show outgoing solids as a function of impulse. Note that the legends are coded by pivot position, felt type and felt moisture.

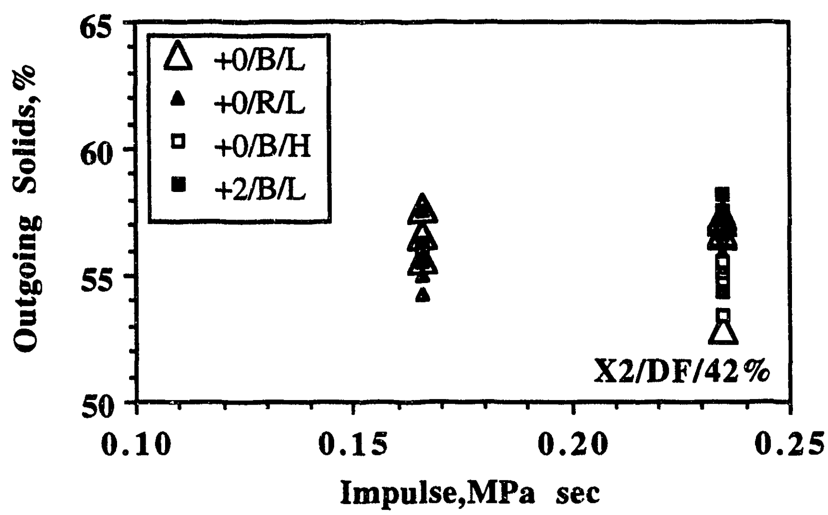


Figure 27. Outgoing Solids as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 42%.

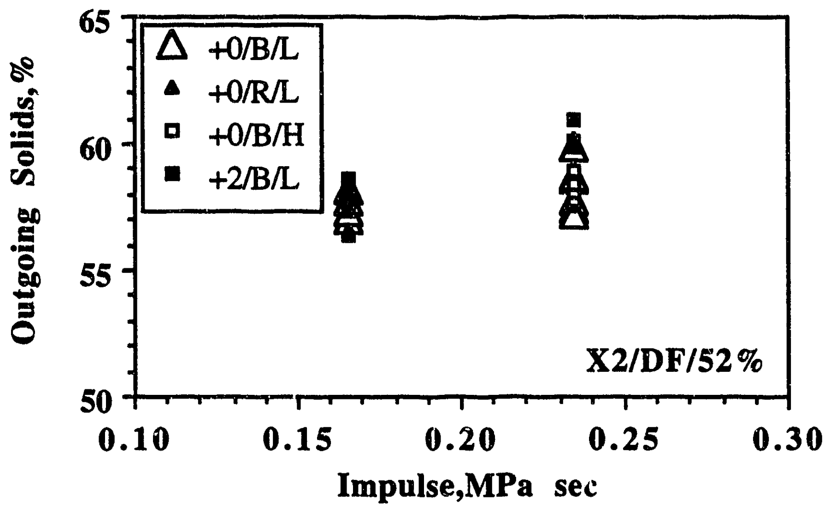


Figure 28. Outgoing Solids as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 52%.

Outgoing solids was found to be independent of felt type and ingoing felt moisture and may be correlated to the same independent variables previously determined for press X1.

%Sout = 45.798+4.678(Impulse)+0.213(%Sin)+0.457(Pivot)

Comparison of the correlations shows that the X2 data is less sensitive to changes in impulse and changes of pivot position than the X1 data.

Physical properties are presented as a function of impulse as shown in Figure 29 through 38. In addition, stepwise regression techniques have been used to determine their dependence on process variables. Felt moisture has been excluded from the regression as it was shown not to be a significant variable. The regressions are of the following form;

Property = A+B(Impulse)+C(%Sin)+D(Pivot)+E(BWT)+F(FLT)

Where the coefficients are given in Table 14 and where; impulse is in MPa·sec., %Sin is in percent, Pivot takes values of -1.0, 0.0, 2.0., Basis Weight is in g/m^2, and Felt type takes on values B=0, R=1.

Table 14. Physical Properties Resulting From Double Felted Pressing On The Beloit X2 Shoe Press

Property	Units	A	B Imp.	C %Sin	D Pivot	E BWT	F FLT
IPC Density	g/cm^3	0.498	0.354	0.003	0.043		0.037
Burst Index (W.Side)	$kPa{\cdot}m^2/g$	3.956			0.195		
Burst Index (F. Side)	$kPa{\cdot}m^2/g$	5.002		-0.03	0.258		
MD STFI Index	N·m/g	48.408		0.192		-.103	1.763
CD STFI Index	N·m/g	14.617	14.12	0.075	1.256		2.768

Comparing the IPC density correlations of Table 13 and 14, double felted pressing on the X2 shoe press was substantially less sensitive to impulse than was the X1 press.

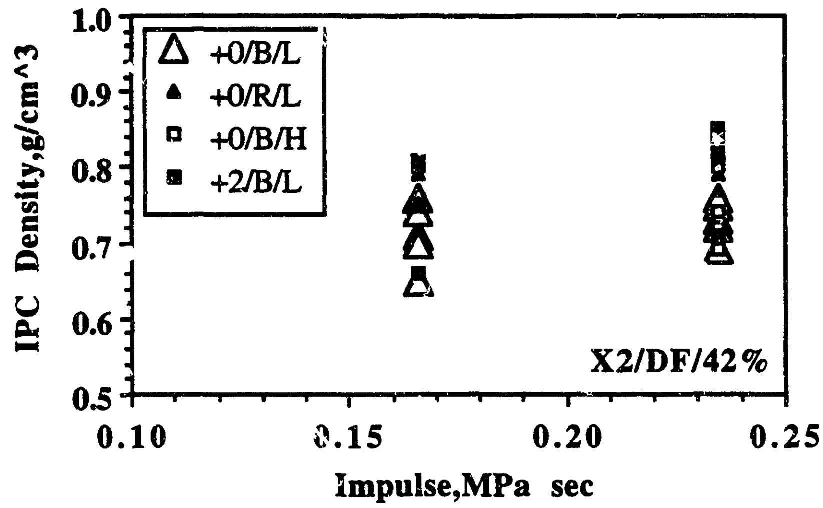


Figure 29. IPC Density as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 42%.

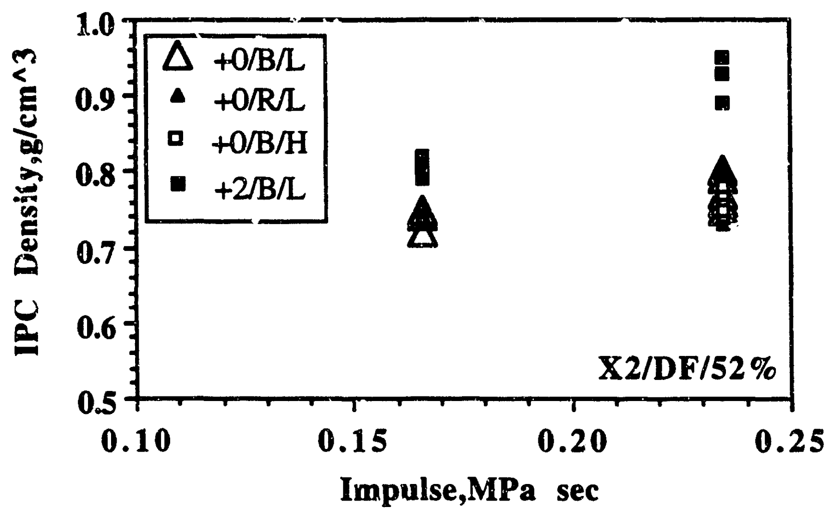


Figure 30. IPC Density as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 52%.

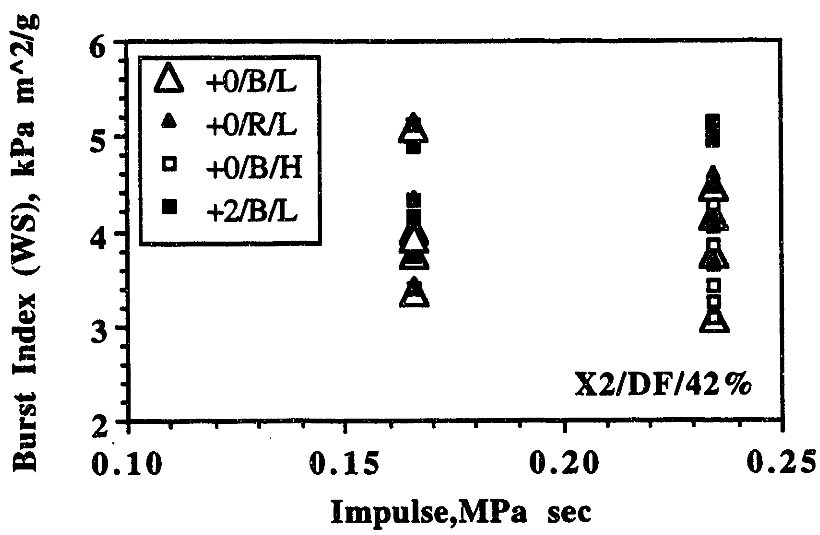


Figure 31. Wire Side Burst Index as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 42%.

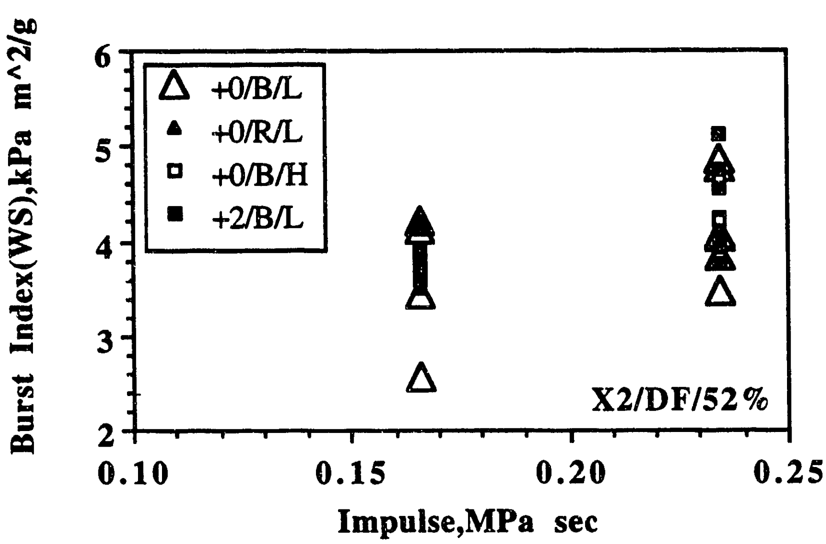


Figure 32. Wire Side Burst Index as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 52%.

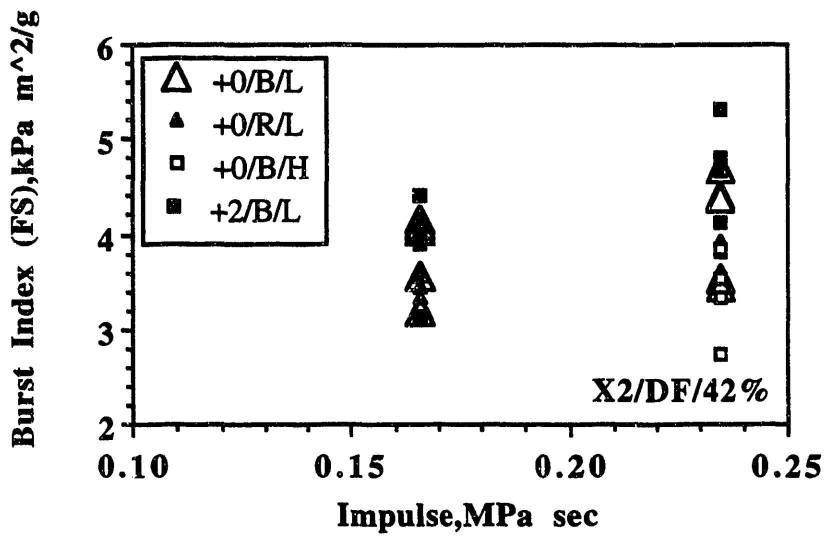


Figure 33. Felt Side Burst Index as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 42%.

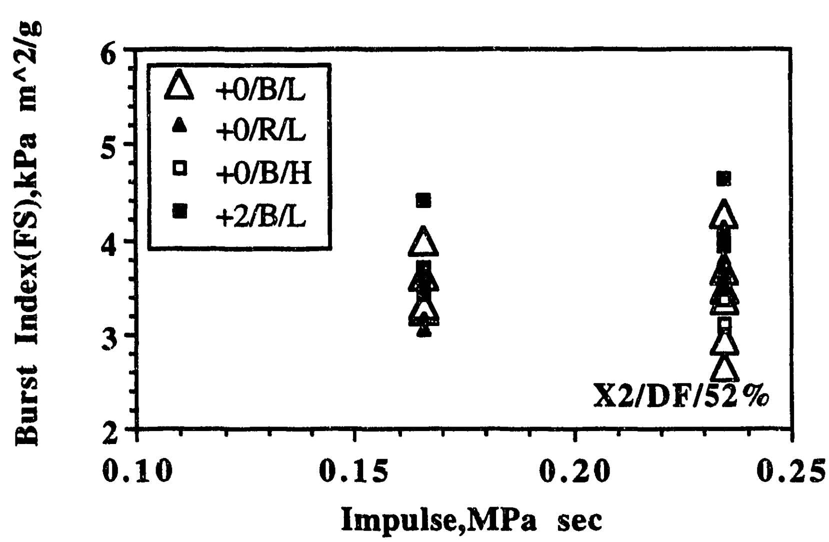


Figure 34. Felt Side Burst Index as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 52%.

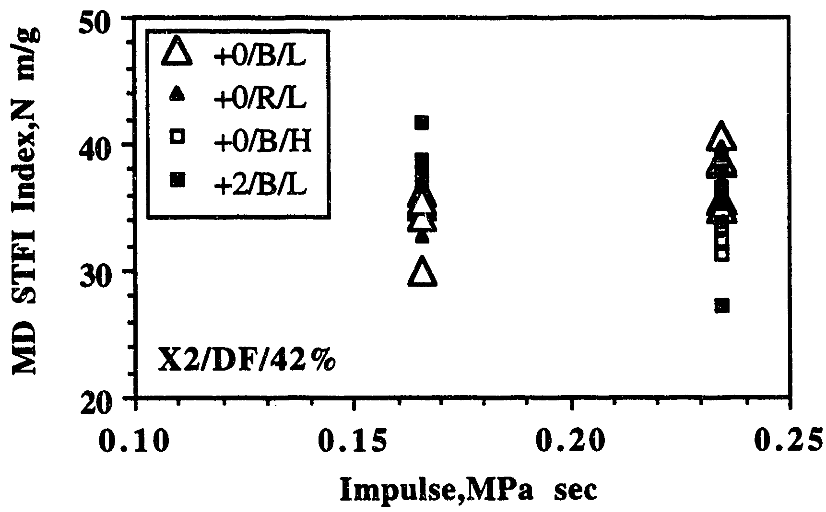


Figure 35. MD STFI Index as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 42%.

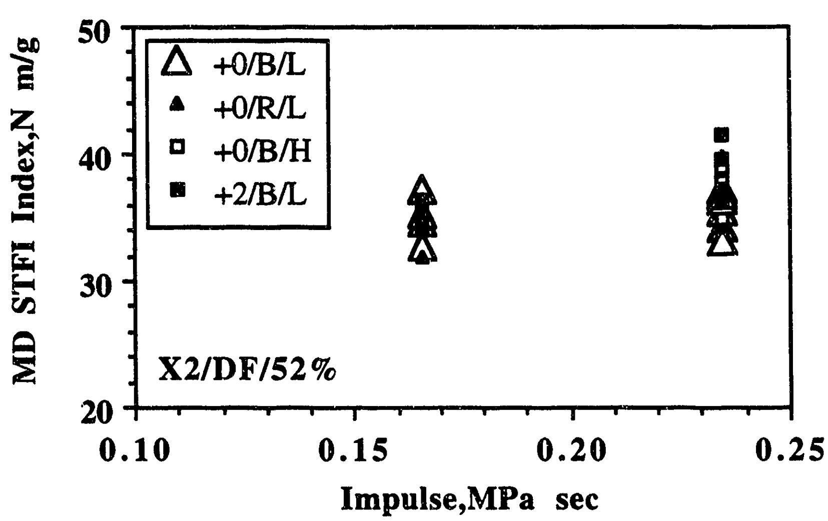


Figure 36. MD STFI Index as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 52%.

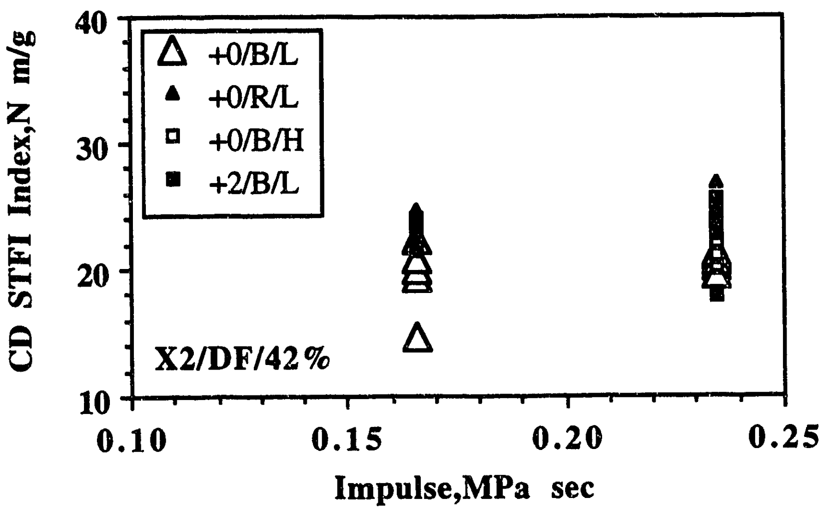


Figure 37. CD STFI Index as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 42%.

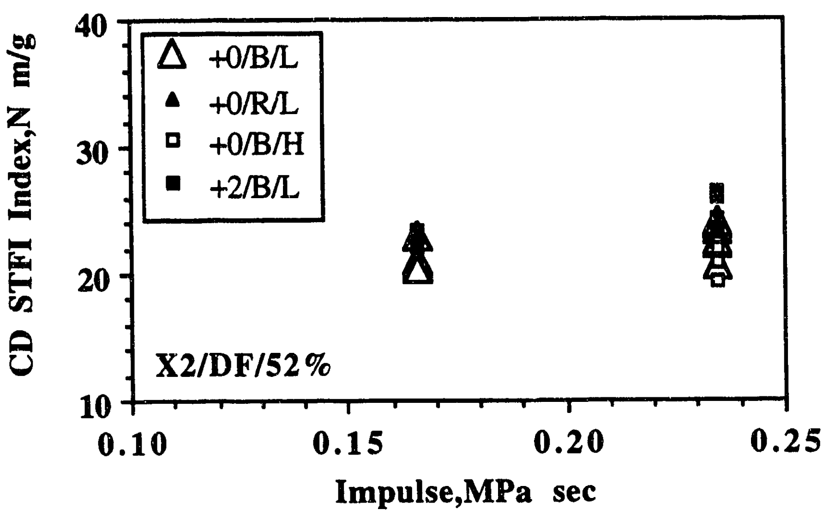


Figure 38. CD STFI Index as a Function of Impulse for Double Felted Pressing on the Beloit X2 Shoe Press from an Ingoing Solids of 52%.

It was expected that STFI Index would be linearly dependent on IPC Density and that the slope would be independent of experimental apparatus. As shown in Figure 39 and 40, STFI Index was a linear function of IPC Density, but the slope was not independent of the press used. The figures show that at high sheet densities the X1 press yielded significantly higher STFI Index than the X2 press.

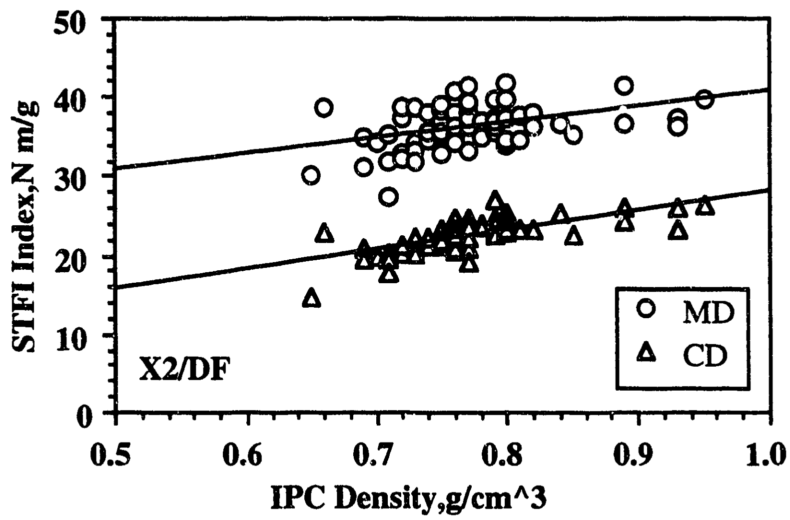


Figure 39. STFI Index as a Function of IPC Density for Double Felted Pressing on the Beloit X2 Shoe Press from 42 and 52% Ingoing Solids.

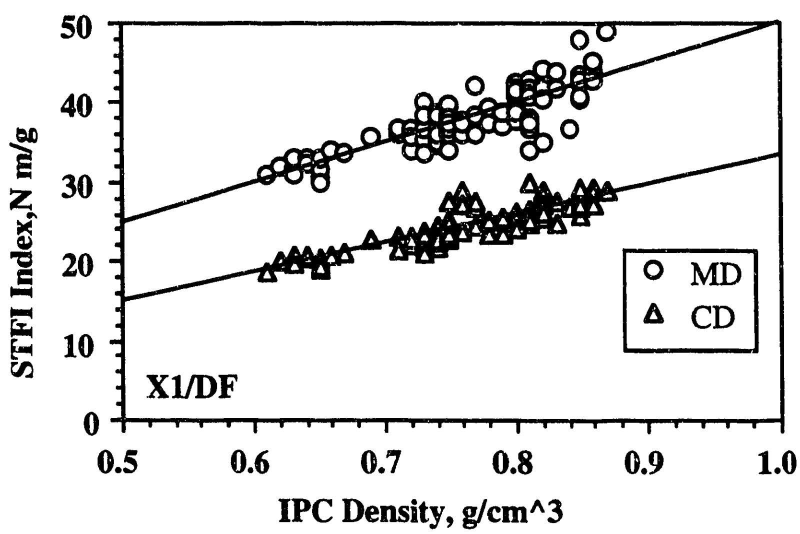


Figure 40. STFI Index as a Function of IPC Density for Double Felted Pressing on the Beloit X1 Shoe Press from 42 and 52% Ingoing Solids.

A similar effect was observed in examining the relationship between Burst index and IPC Density as shown in Figure 41 and 42.

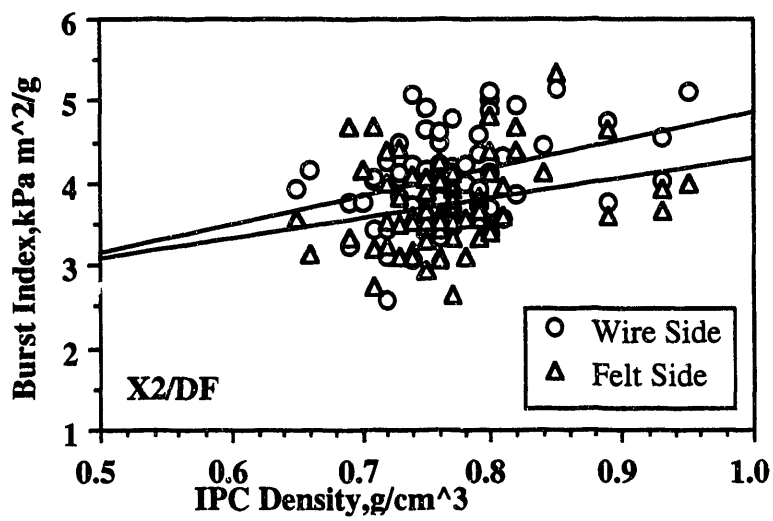


Figure 41. Burst Index as a Function of IPC Density for Double Felted Pressing on the Beloit X2 Shoe Press from 42 and 52% Ingoing Solids.

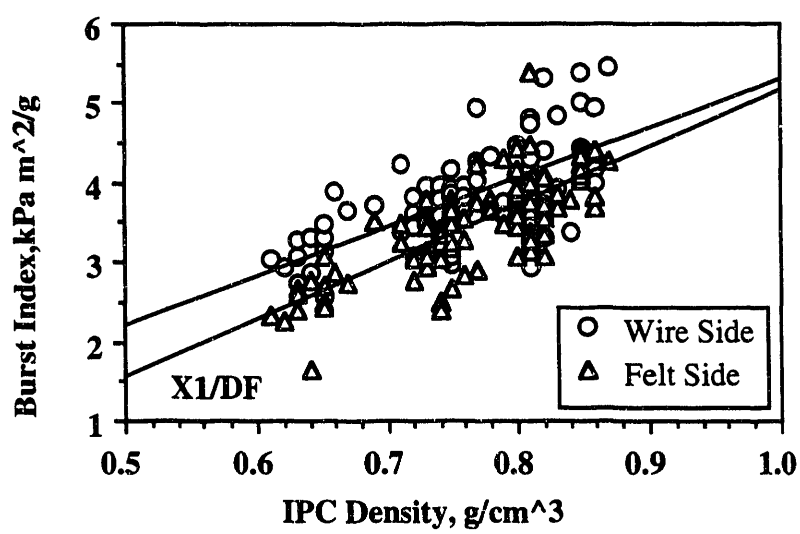


Figure 42. Burst Index as a Function of IPC Density for Double Felted Pressing on the Beloit X1 Shoe Press from 42 and 52% Ingoing Solids.

Impulse Drying

In this section impulse drying results are presented for experiments performed with both Ceramic Coated and Beloit Type C rolls installed on the Beloit X2 shoe press. In addition, the results of roll press experiments are also presented.

The focus of the impulse drying experiments was to determine the critical impulse drying roll temperature for each of the various process modifications. Following the definition established in earlier IPST research, the critical impulse drying temperature was defined as the highest roll surface temperature above which sheet delamination occurred. As in past research, sheet delamination was detected by out-of-plane ultrasonic measurements. The procedure consisted of graphing the mean value of the specific elastic modulus and its coefficient of variation as a function of roll surface temperature. Previous research has shown that as the roll temperature is increased the elastic modulus increases until sheet delamination occurs. At the temperature where delamination first occurs the elastic modulus will drop and its coefficient of variation will increase. Hence the experimental roll temperature just preceding this event is termed the critical impulse drying temperature.

For clarity the graphs used to determine critical temperatures are shown in the appendix.

The results of experiments with the Ceramic Coated roll, on the Beloit X2 Shoe press, are graphed as a function of roll surface temperature in Figure 43 through 52. Ultrasonic data used to determine critical temperatures are given in Figure A1 through A10. Table 15 summarizes for each process modification the critical temperature and the outgoing solids and physical properties at the critical temperature.

Table 15 . Critical Temperature And Fitted Properties At The Critical Temperature For Impulse Drying X2 Press Ceramic Roll

Ingoing Solids, %	42						52					
Impulse, psi·seconds	16 psi sec		24 psi sec		34 psi sec		16 psi sec		24 psi sec		34 psi sec	
Felt Moisture	L	H	L	H	L	H	L	H	L	H	L	H
$T_{crit.}$, °C	148	NA	204	260	204	315	260	NA	260	260	260	260
Outgoing Solids, %	55.6		54.0	53.1	54.9	55.5	56.6		61.0	56.0	60.5	60.2
IPC Density,g/cm^3	0.76		0.73	0.66	0.78	0.77	0.76		0.81	0.75	0.86	0.82
MDSTFI Index,N·m/g	34.3		35.7	31.3	36.5	34.3	35.7		37.3	31.3	39.3	38.1
CDSTFI Index, N·m/g	22.3		22.3	19.3	22.5	22.9	23.6		23.7	23.6	25.8	24.1
WS Burst I.,kPa·m^2/g	3.96		4.73	3.17	4.08	3.84	3.80		4.10	4.10	3.85	4.10
FS Burst I., kPa·m^2/g	3.74		4.36	3.53	4.03	4.19	3.84		3.83	3.68	4.28	4.15

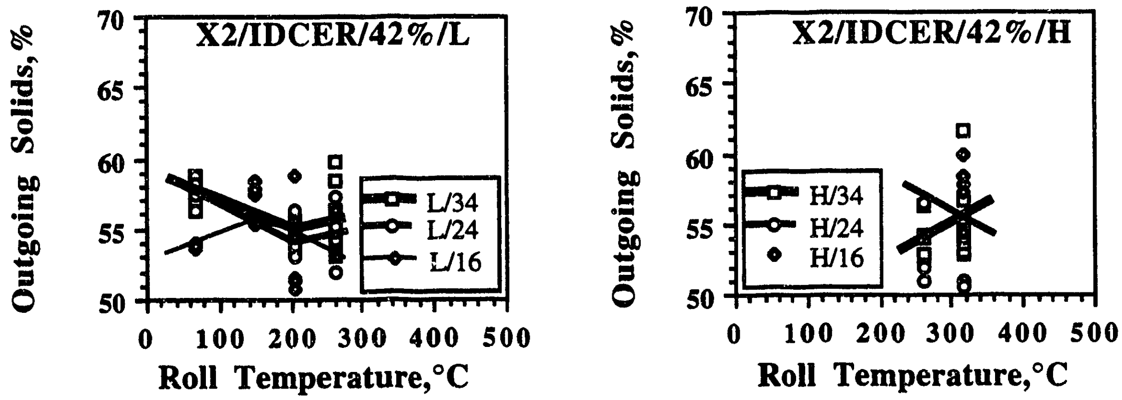


Figure 43. Outgoing Solids as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

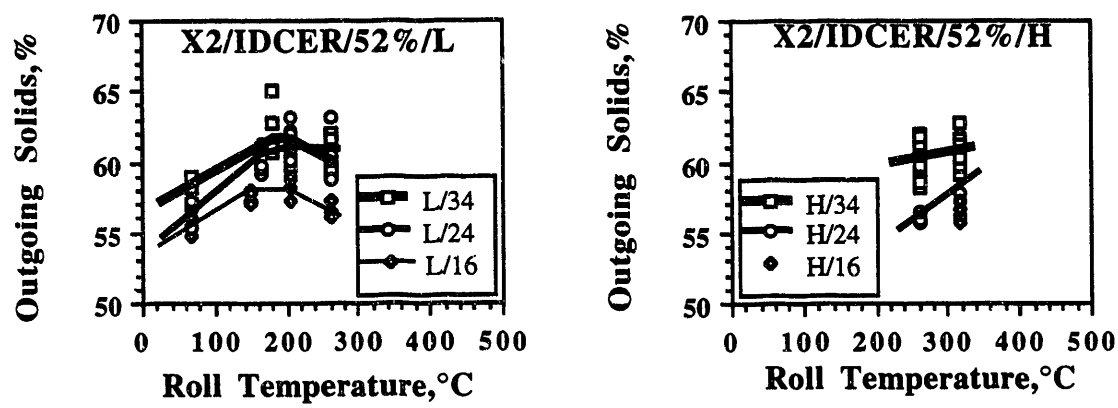


Figure 44. Outgoing Solids as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

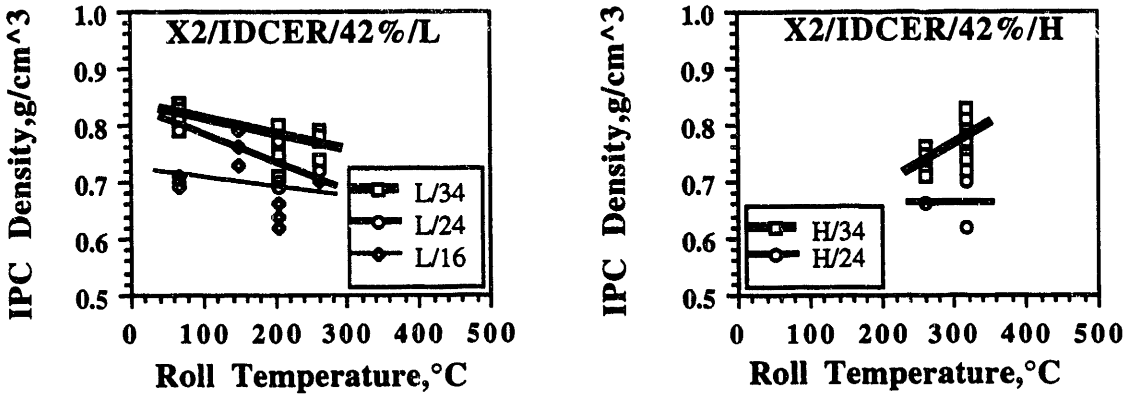


Figure 45. IPC Density as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

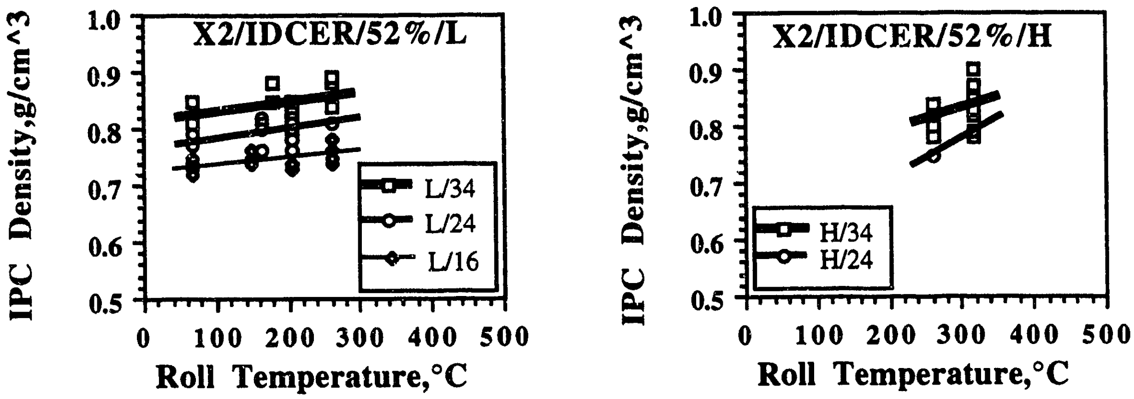


Figure 46. IPC Density as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

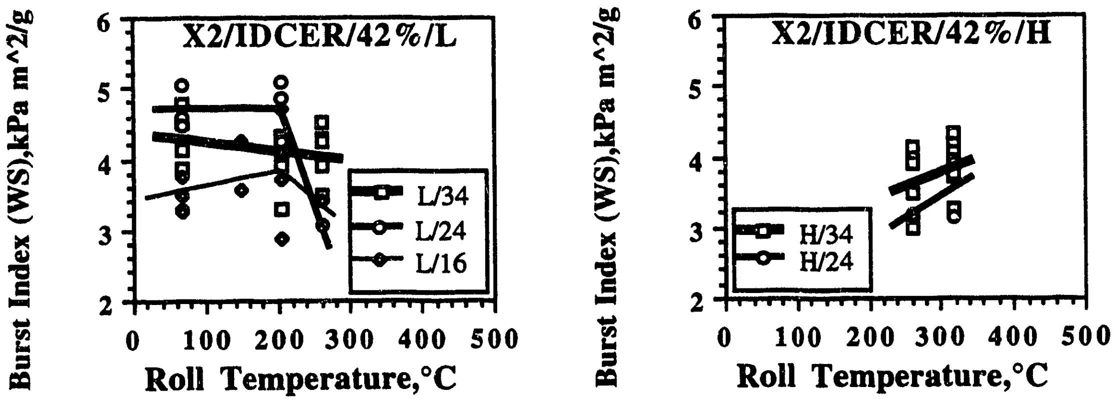


Figure 47. Wire Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

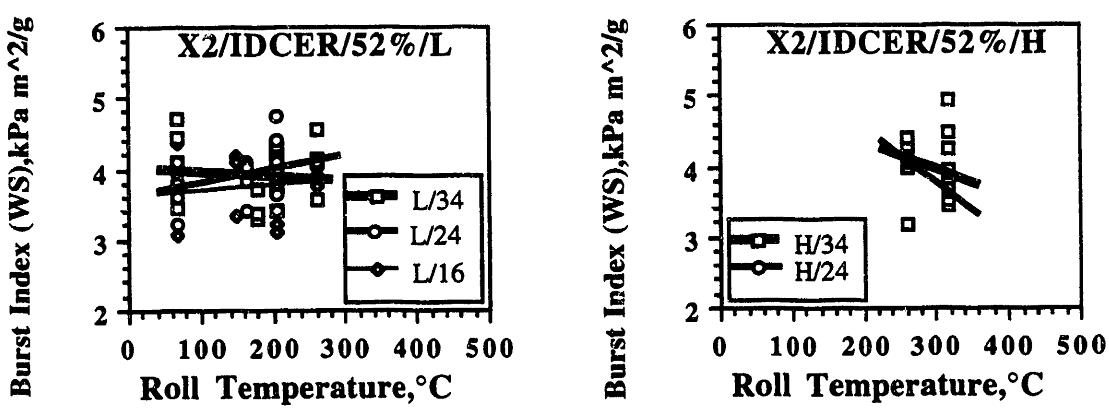


Figure 48. Wire Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

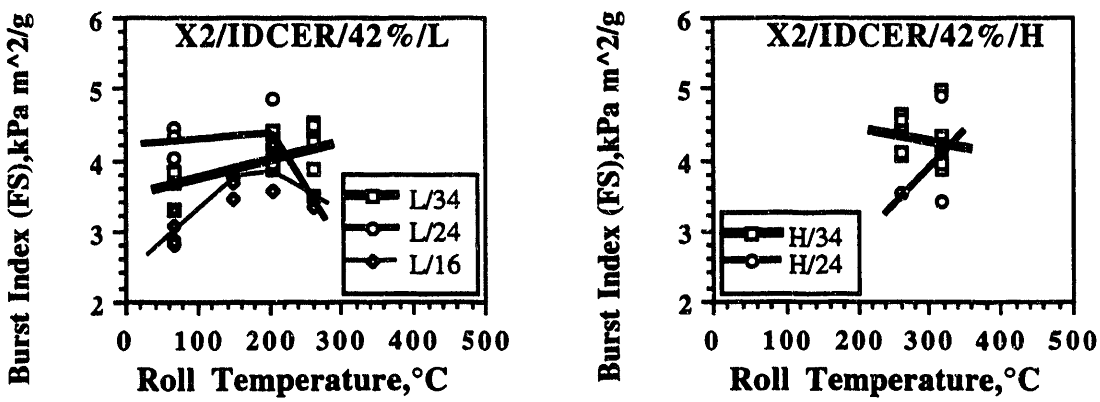


Figure 49. Felt Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

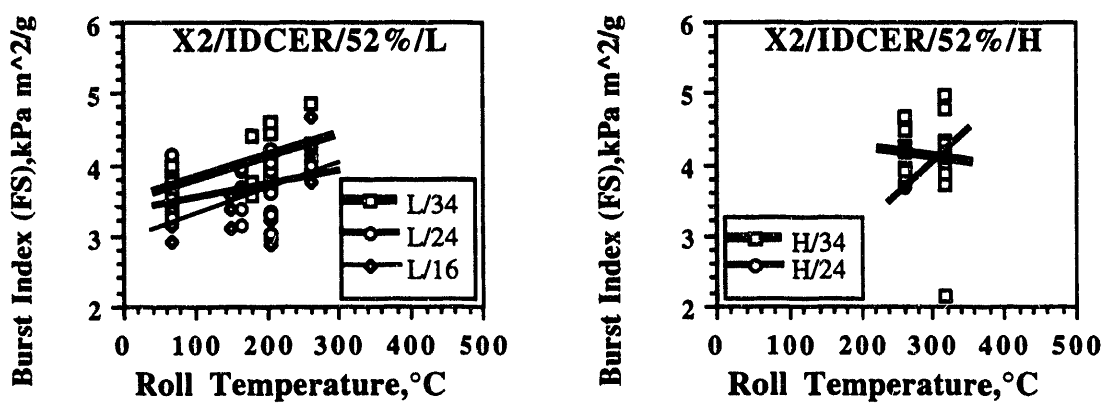


Figure 50. Felt Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

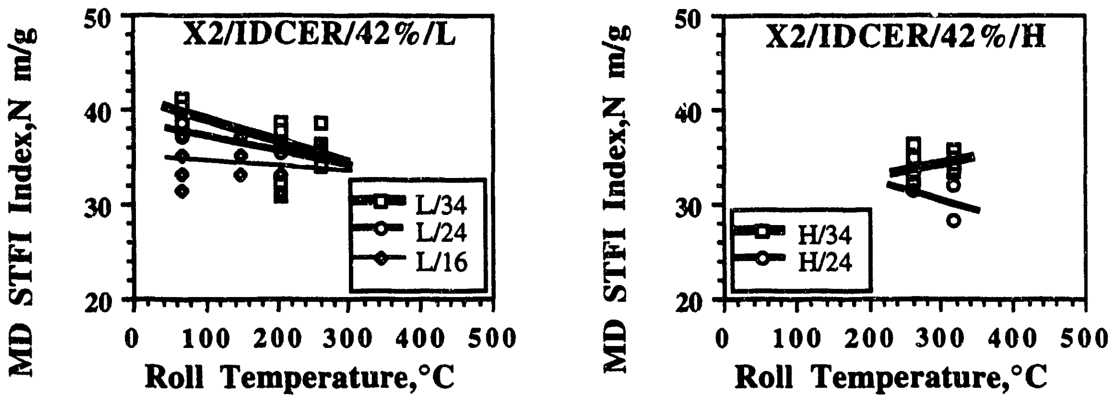


Figure 51. MD STFI Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

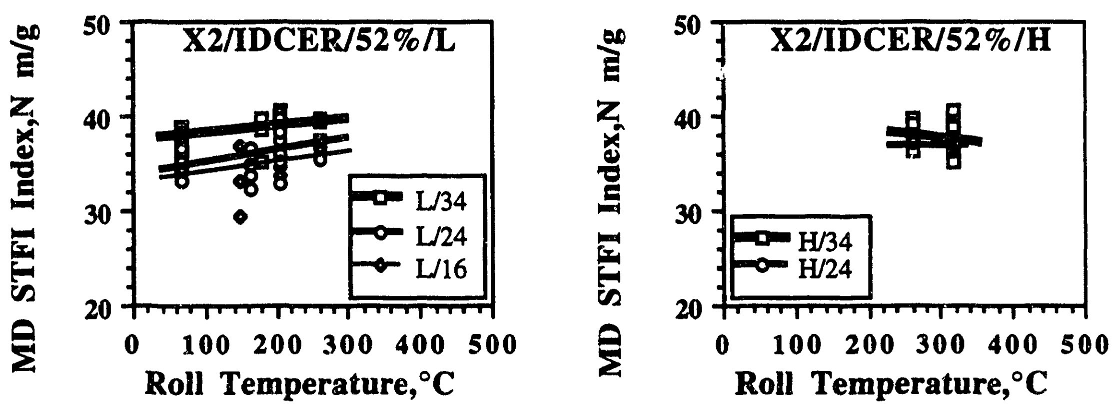


Figure 52. MD STFI Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

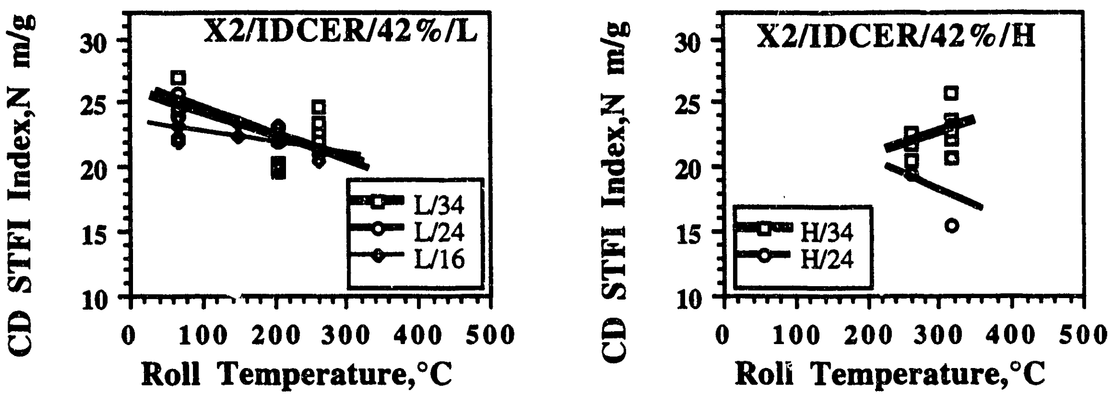


Figure 53. CD STFI Index as a Function of Roll Temperature
for Impulse Drying with the Ceramic Coated Roll on the Beloit X2
Shoe Press from 42 % Ingoing Solids.

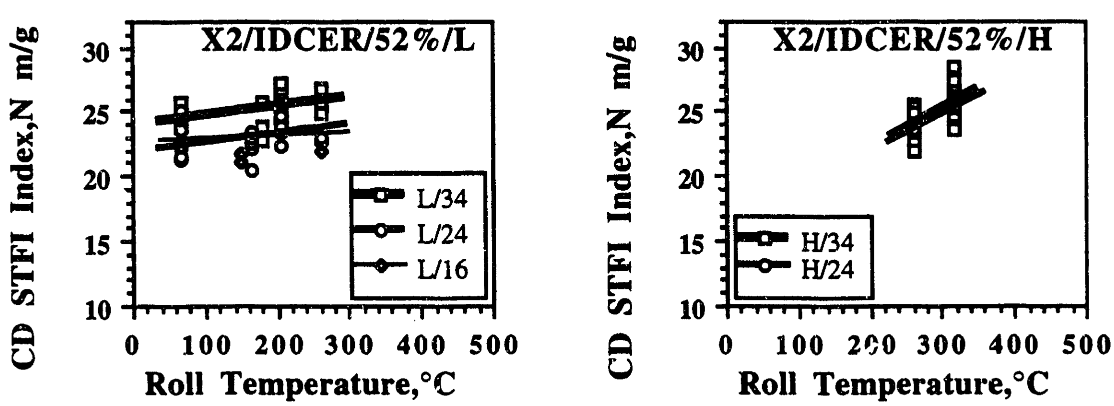


Figure 54. CD STFI Index as a Function of Roll Temperature
for Impulse Drying with the Ceramic Coated Roll on the Beloit X2
Shoe Press from 52 % Ingoing Solids.

The results of experiments with the Beloit Roll C, on the Beloit X2 shoe press, are graphed as a function of roll surface temperature in Figure 55 through 67. Ultrasonic data used to determine critical temperatures are given in Figure A11 through A20. Table 16 summarizes for each process modification the critical temperature and the outgoing solids and physical properties at the critical temperature.

Table 16. Critical Temperature and Resulting Physical Properties for Impulse Drying on the X2 Extended Nip Press Using the Beloit Roll C

Ingoing Solids,%	42					52				
Pivot Position	0			+2		0			+2	
Felt Type	R		B	B		R		B	B	
Impulse,psi seconds	34		34	24	34	34		34	24	34
Felt Moisture	L	H	L	L	L	L	H	L	L	L
$T_{crit.}$, °C	204	148	148	148	148	204	204	204	204	260
Sout, %	66.4	62.8	61.1	58.1	61.3	66.0	67.7	65.5	64.9	65.6
IPC Density, g/cm^3	0.87	0.85	0.84	0.84	0.89	0.88	0.88	0.91	0.93	0.93
MDSTFI Index,N·m/g	37.9	39.5	38.0	35.3	36.5	39.4	38.6	39.1	37.3	37.2
CDSTFI Index,N·m/g	26.2	25.4	25.8	23.8	25.1	25.6	26.1	25.3	24.5	26.2
WS Burst Ind.,kPam^2/g	5.11	4.41	4.42	4.53	4.40	5.02	4.35	4.35	3.72	3.94
FS Burst Ind.,kPam^2/g	4.94	4.77	3.94	4.37	4.33	5.05	5.08	4.26	4.17	5.09

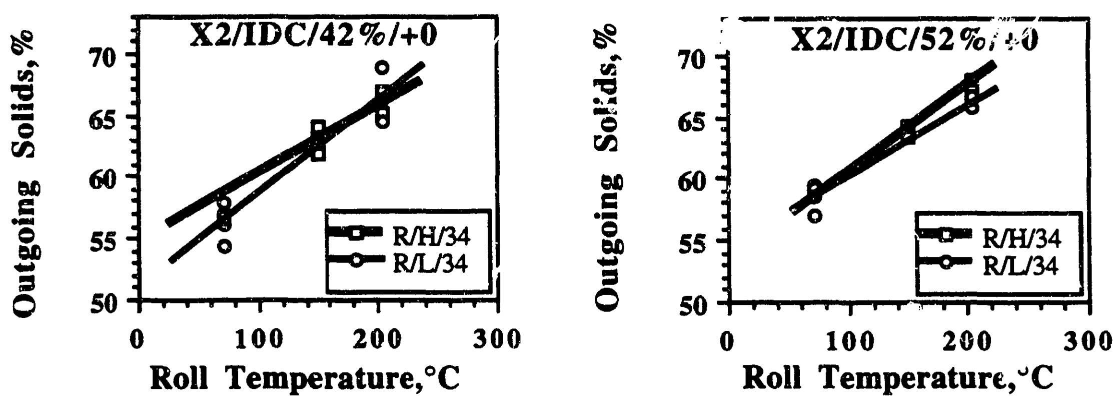


Figure 55. Outgoing Solids as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 42 and 52 % Ingoing Solids at Low and High Felt Moisture. "0" Pivot, Felt R, 34 psi seconds Impulse.

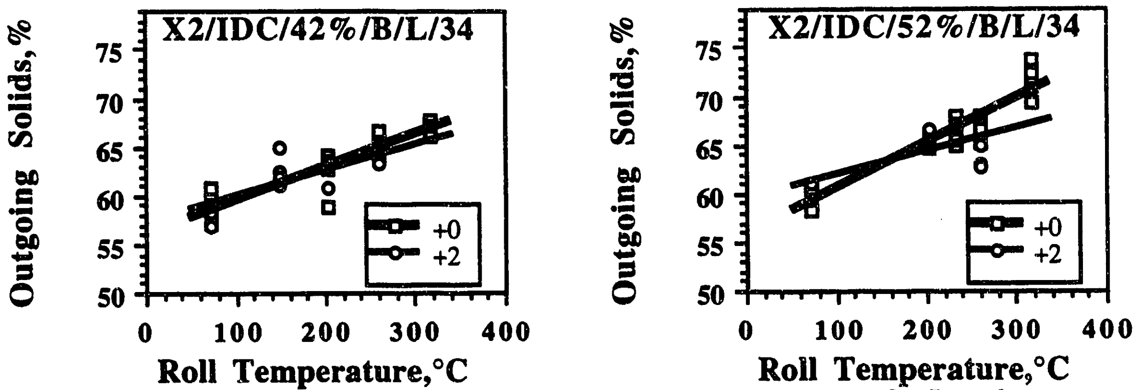


Figure 56. Outgoing Solids as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 42 and 52 % Ingoing Solids at Low Felt Moisture. "0" and "+2" Pivot, Felt B, 34 psi seconds Impulse.

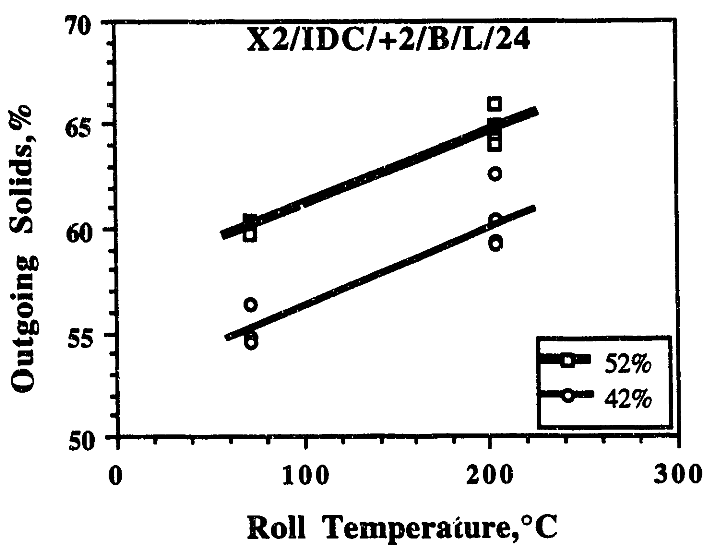


Figure 57. Outgoing Solids as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 42 and 52 % Ingoing Solids at Low Felt Moisture. "+2" Pivot, Felt B, 24 psi seconds Impulse.

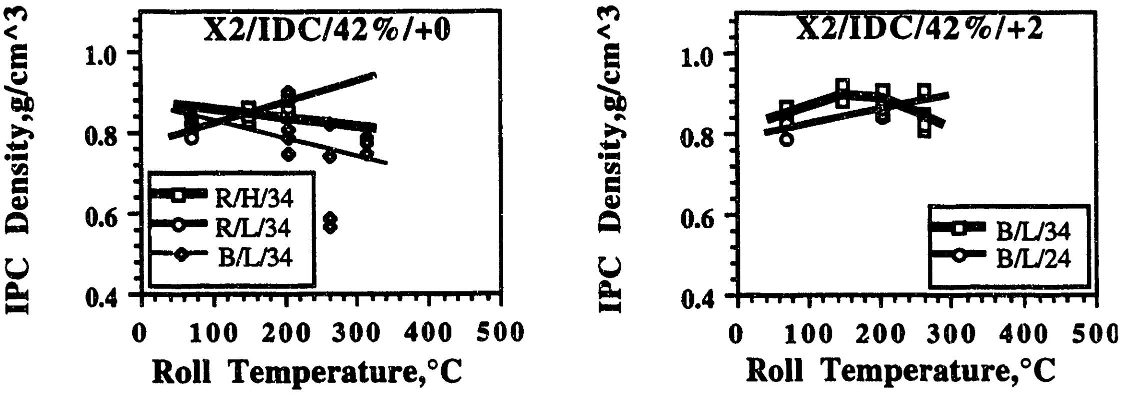


Figure 58. IPC Density as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

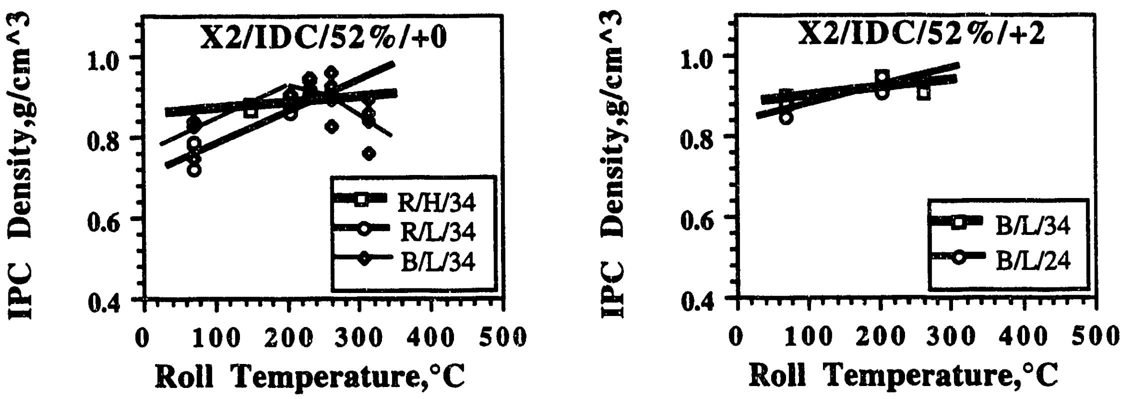


Figure 59. IPC Density as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

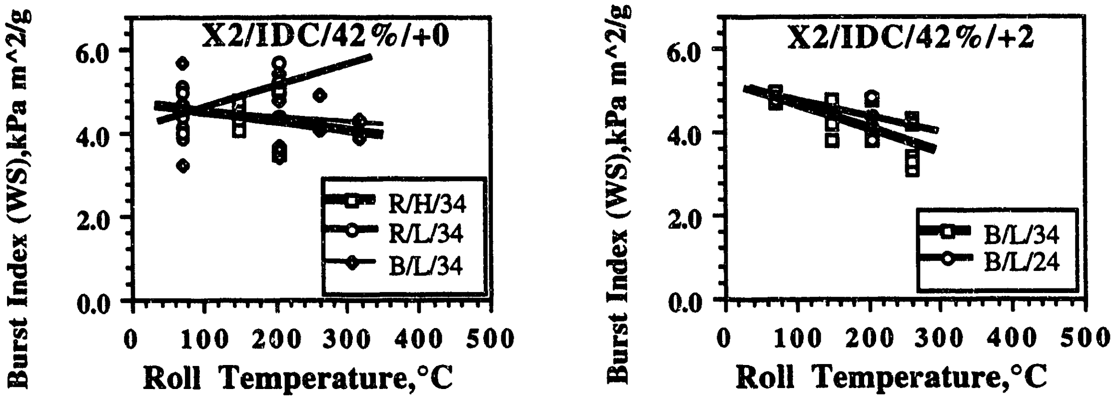


Figure 60. Wire Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

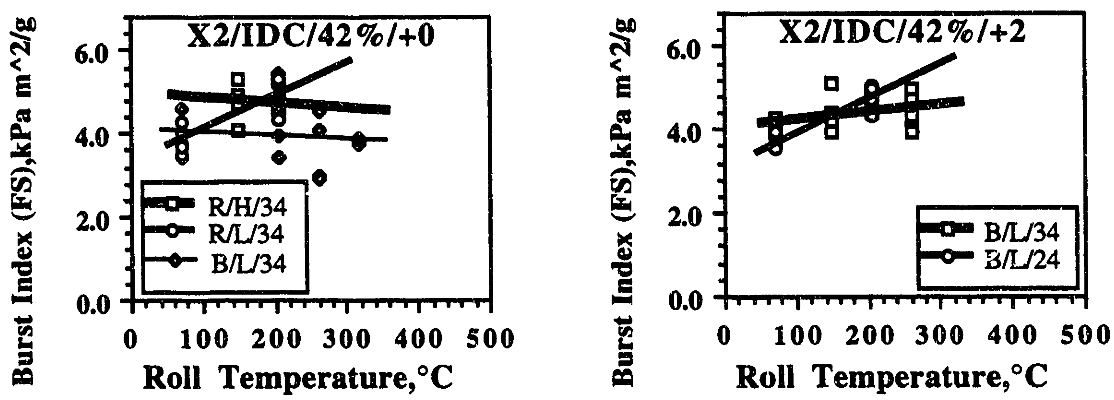


Figure 61. Felt Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

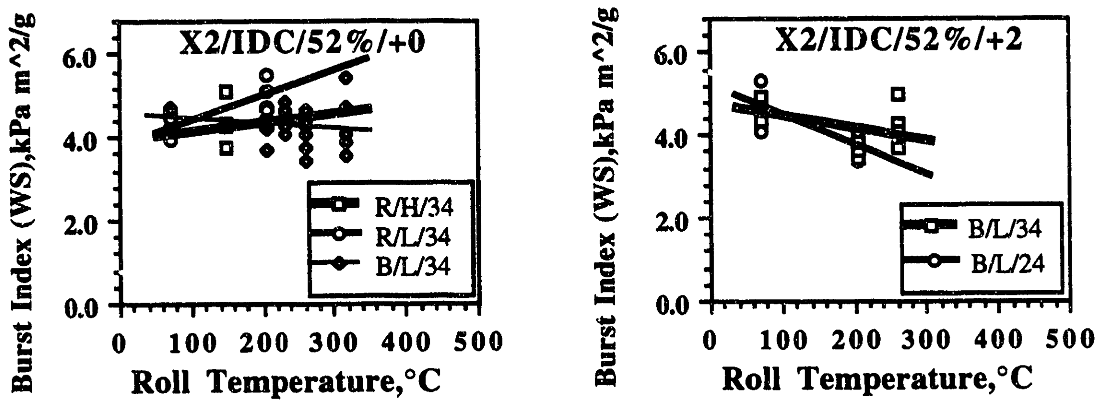


Figure 62. Wire Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

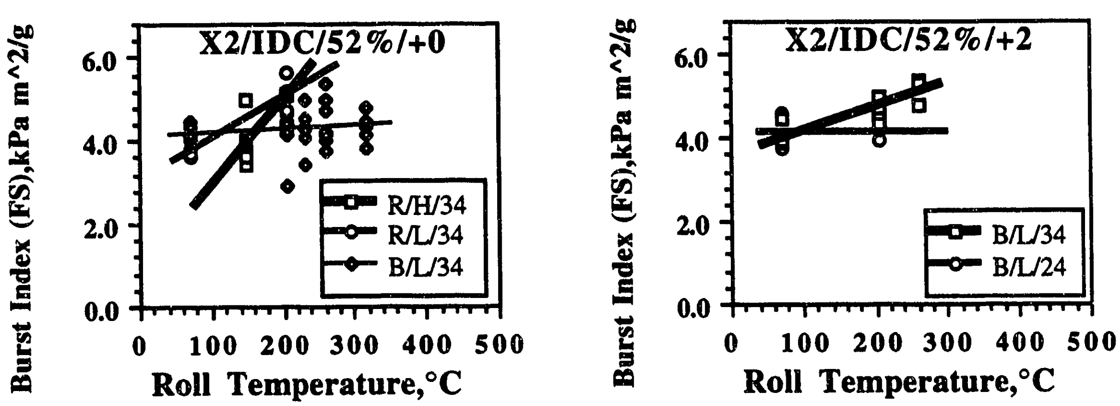


Figure 63. Felt Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

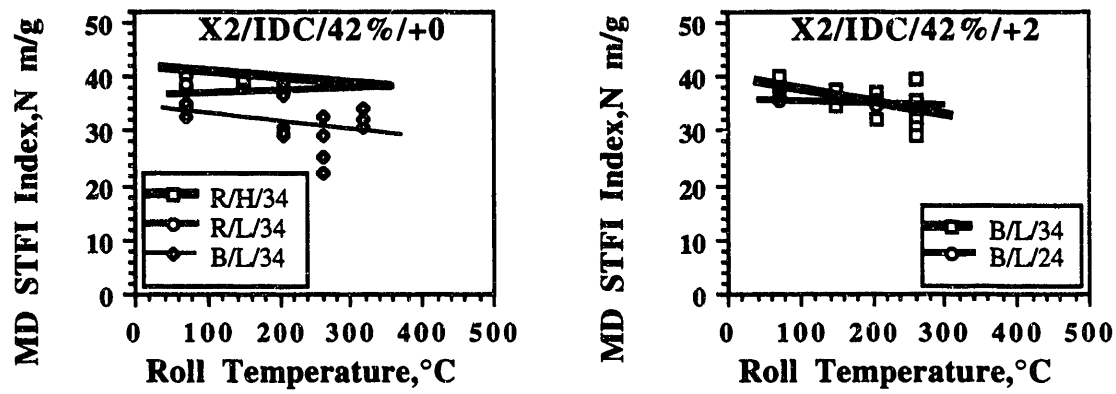


Figure 64. IPC MDSTFI Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

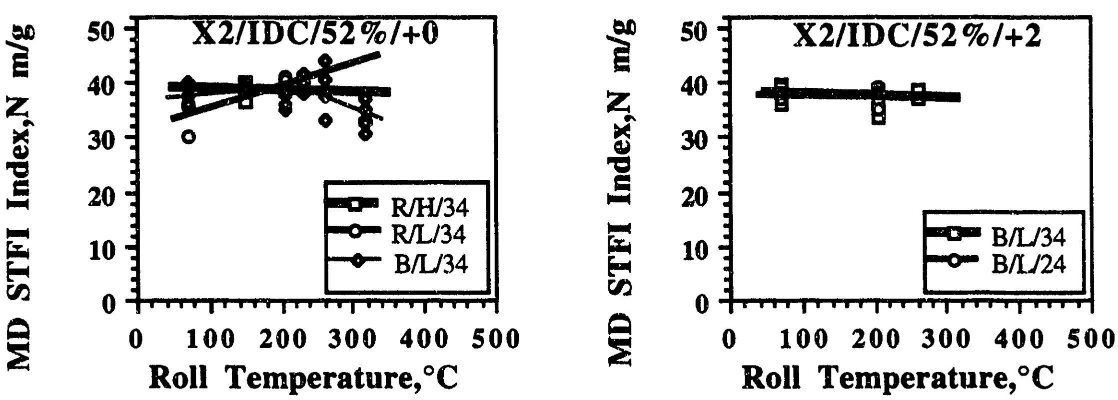


Figure 65. MD STFI Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

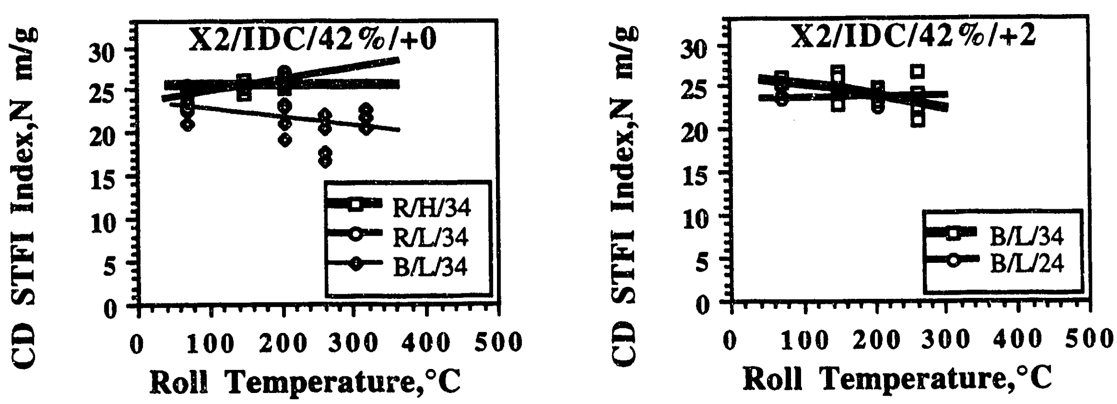


Figure 66. CD STFI Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 42 % Ingoing Solids.

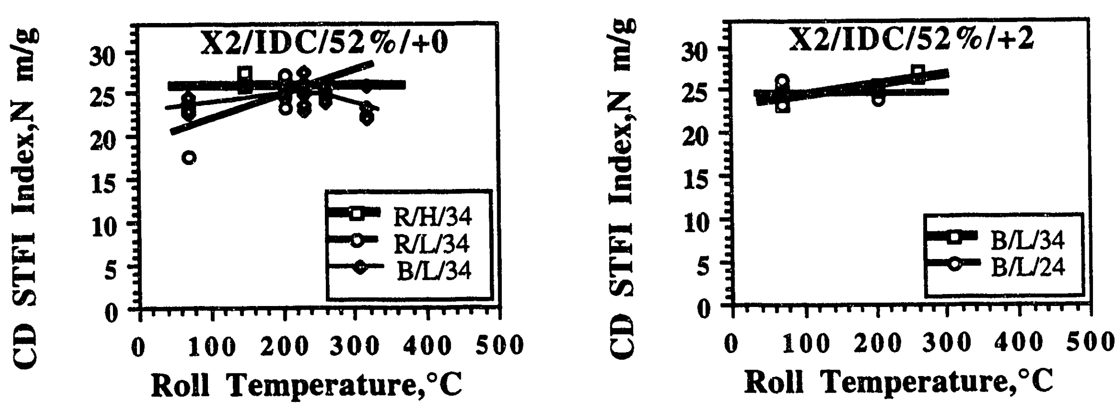


Figure 67. CD STFI Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit X2 Shoe Press from 52 % Ingoing Solids.

The results of experiments with the Ceramic Coated roll, on the IPST Pilot roll press, and the Beloit Roll C, on the Beloit HRP roll press, are graphed as a function of roll surface temperature in Figure 68 through 74. Ultrasonic data used to determine critical temperatures are given in Figure A21 through A25. Table 17 summarizes for each process modification the critical temperature and the outgoing solids and physical properties at the critical temperature.

Table 17. Critical Temperature And Resulting Physical Properties For Impulse Drying On The IPST Roll Press Using The Ceramic Coated Roll And Beloit Roll Press Using The Beloit Roll C

Ingoing Solids,%	42			52	
Press Roll Type	IPST Ceramic Coated		Beloit Roll C	IPST Ceramic Coated	
Press Load, pli	315	472	530	315	472
Speed, fpm	100	100	78	100	100
Impulse,psi seconds	16	24	34	16	24
Felt Moisture	Low	Low	Low	Low	Low
$T_{crit.}$, °C	350	300	266	350	300
Sout, %	60.5	60.5	62.2	61.1	61.3
IPC Density,g/cm^3	nm	nm	0.82	nm	nm
MDSTFI Index, N·m/g	30.9	31.7	35.7	33.8	31.7
CDSTFI Index, N·m/g	20.1	20.4	23.4	23.0	21.4
WS Burst Ind., kPa·m^2/g	3.65	3.71	4.14	3.87	3.46
FS Burst Ind. , kPa·m^2/g	nm	nm	4.52	nm	nm

Table 18 shows the results of a double felted pressing experiments in which the Beloit HRP roll press was operated in the double felted mode. Impulse drying may be directly compared to double felted pressing by comparing the Beloit HRP data of Table 17 and 18. Even at an ingoing solids of 42%, impulse drying resulted in a twelve additional percentage points in dryness, while MD STFI Index increased from 29.9 to 35.7 N·m/g.

Table 18. Physical Properties for Double Felted Wet Pressing on the Beloit Roll Press

Ingoing Solids, %	42
Press Load,pli	530
speed, fpm	78
Impulse,psi seconds	34
Felt Moisture	Low
Sout, %	50.3
IPC Density, g/cm^3	0.66
MDSTFI Index, N·m/g	29.9
CDSTFI Index, N·m/g	18.3
WS Burst Ind., kPa·m^2/g	3.29
FS Burst Ind., kPa·m^2/g	2.74

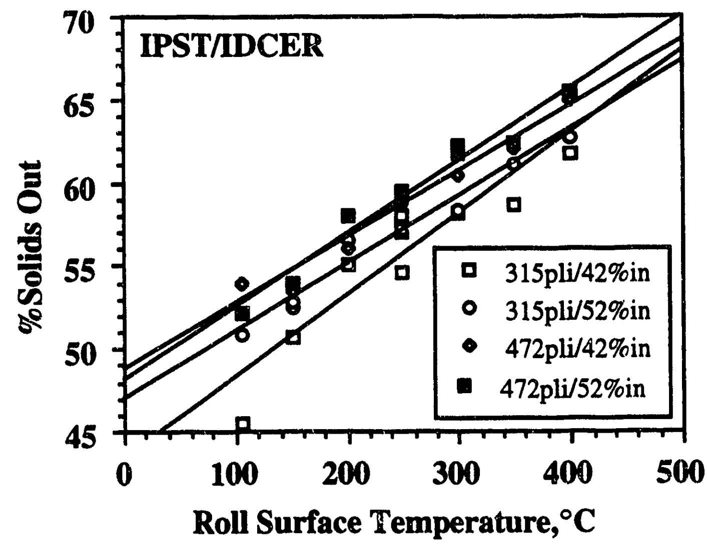


Figure 68. Outgoing Solids as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the IPST Pilot Roll Press.

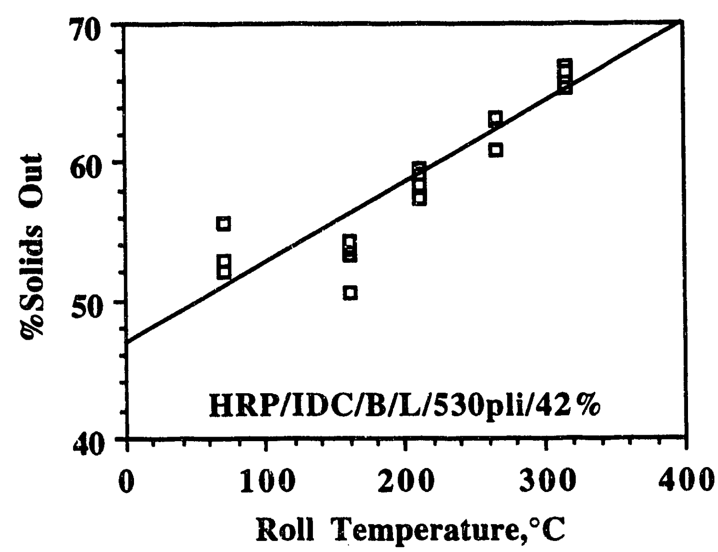


Figure 69. Outgoing Solids as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit HRP Roll Press.

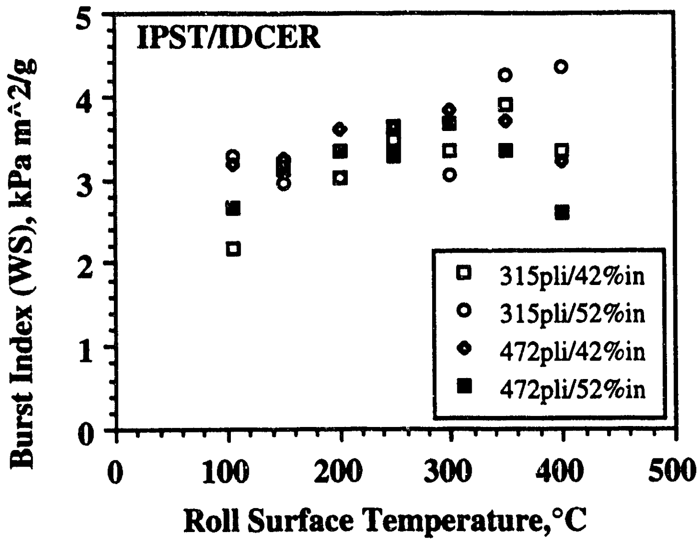


Figure 70. Wire Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the IPST Pilot Roll Press.

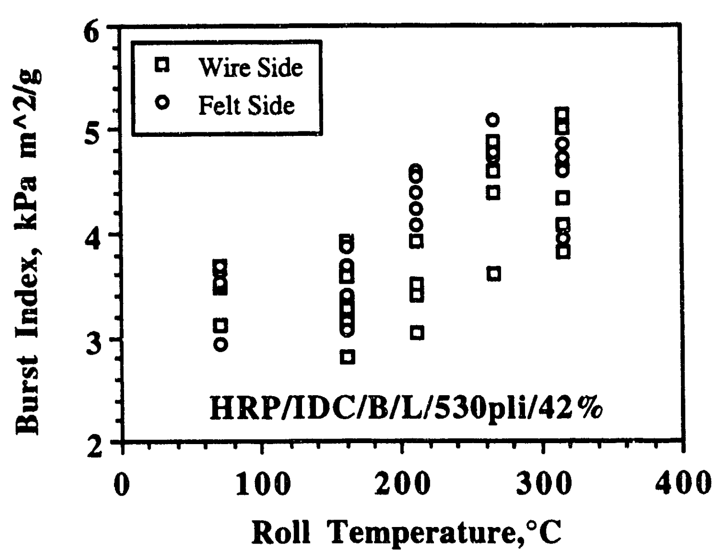


Figure 71. Wire and Felt Side Burst Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit HRP Roll Press.

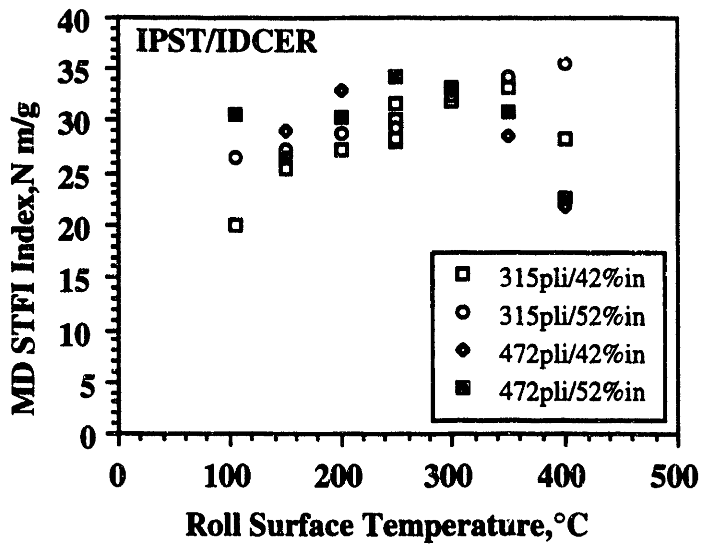


Figure 72. MD STFI Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the IPST Pilot Roll Press.

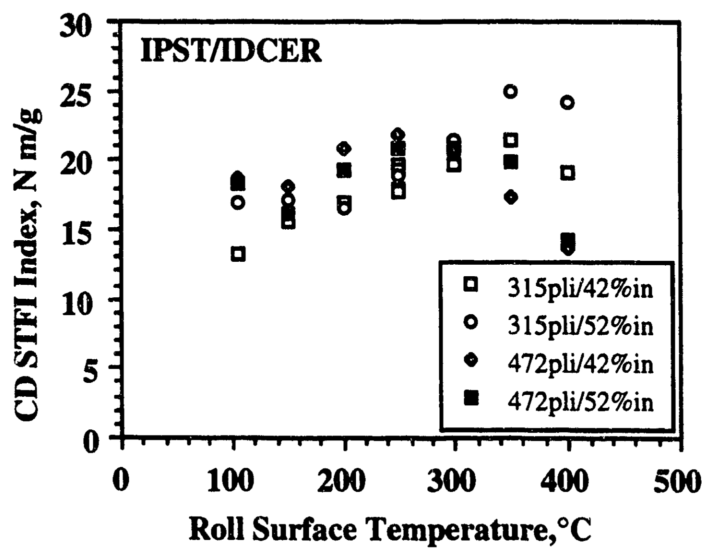


Figure 73. CD STFI Index as a Function of Roll Temperature for Impulse Drying with the Ceramic Coated Roll on the IPST Pilot Roll Press.

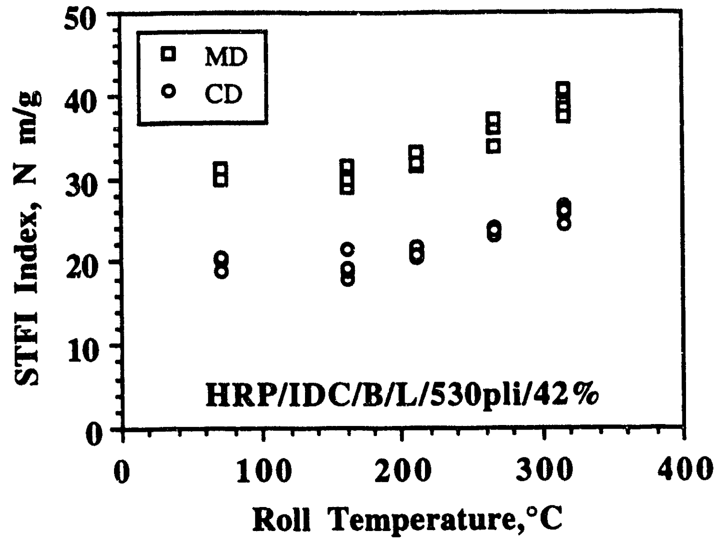


Figure 74. MD and CD STFI Index as a Function of Roll Temperature for Impulse Drying with the Beloit Roll C on the Beloit HRP Roll Press.

<u>Sheet Sticking Issue:</u>

The phenomena of sheet sticking to the various roll surfaces was not observed in either of the roll press experiments. Sheet sticking was observed during impulse drying experiments conducted on the Beloit X2 Shoe press. During the experiments various observers saw a dependence of sticking on the choice of press roll, roll temperature, pressure and felt moisture. In addition, observers concluded that sticking seemed to be more prevalent on one side of the machine. In all of the experiments handsheets were introduced into the press in the same way, with the sheet numbering facing forward and upward. It was also observed that when the sheet stuck to the roll it resulted in surface picking. In order to quantify the phenomena, sheets produced during the experiments were visually inspected to determine whether they stuck and if so which side of the machine was involved. From this information, the probability of sticking on each side of the ceramic and Beloit Type C rolls were documented as shown in Table 19.

Table 19. Probability of the Handsheet Sticking on the Surface of the Press Roll During Impulse Drying on the Beloit X2 Shoe Press

Roll	Pivot	Felt type	Felt MR	Impulse, psi sec	Roll Temp, °C	Total Events	OPERATOR SIDE STICKING Events	OPERATOR SIDE STICKING Probability %	DRIVE SIDE STICKING Events	DRIVE SIDE STICKING Probability %
CER	0	B	0.25	16	68	10	5	50	8	80
CER	0	B	0.25	16	148	10	4	40	5	50
CER	0	B	0.25	16	204	10	5	50	10	100
CER	0	B	0.25	16	260	10	10	100	5	50
CER	0	B	0.25	24	68	10	5	50	6	60
CER	0	B	0.25	24	166	5	2	40	2	40
CER	0	B	0.25	24	204	15	4	27	13	87
CER	0	B	0.25	24	260	10	10	100	10	100
CER	0	B	0.25	34	68	7	2	29	3	43
CER	0	B	0.25	34	179	5	3	60	5	100
CER	0	B	0.25	34	204	10	2	20	8	80
CER	0	B	0.25	34	260	30	28	93	24	80
CER	0	B	0.50	16	315	10	10	100	10	100
CER	0	B	0.50	24	260	10	10	100	10	100
CER	0	B	0.50	24	316	10	10	100	10	100
CER	0	B	0.50	34	260	34	25	74	33	97
CER	0	B	0.50	34	315	20	15	75	4	80
"C"	0	B	0.25	34	71	10	4	40	10	100
"C"	0	B	0.25	34	204	10	5	50	0	0
"C"	0	B	0.25	34	232	10	10	100	4	40
"C"	0	B	0.25	34	260	15	9	60	5	33
"C"	0	B	0.25	34	315	15	8	53	11	73
"C"	2	B	0.25	24	71	9	8	89	6	67
"C"	2	B	0.25	24	204	10	7	70	4	40
"C"	2	B	0.25	34	71	10	7	70	9	90
"C"	2	B	0.25	34	148	5	0	0	0	0
"C"	2	B	0.25	34	204	9	6	67	3	33
"C"	2	B	0.25	34	260	10	2	20	0	0
"C"	0	R	0.25	34	71	20	18	90	17	85
"C"	0	R	0.25	34	204	10	2	20	2	20
"C"	0	R	0.50	34	148	10	4	40	0	0
"C"	0	R	0.50	34	204	15	11	73	10	67

It is significant to note that sticking frequently occurred on both the Ceramic Coated and Beloit Type C rolls.

Lumping operating conditions together, the probability of sticking on the operator side of the ceramic coated roll was 69% while sticking occurred 77% of the time on the drive side of the same roll. In contrast, there was a 60% probability of sticking on the operator side of the Beloit Roll C roll and a 48% chance of sticking on the drive side.

While the probability of sticking was substantially lower on the operator side of the Ceramic Coated roll than the drive side, increasing temperature tended to increase the probability of sticking. Regressions showed that felt moisture and press load were not significant variables in determining sheet sticking.

For the Beloit Roll C, sticking was a random phenomena that did not correlate to pivot position, felt type, felt moisture, press load or roll surface temperature.

At roll temperatures exceeding 100°C, both rolls accumulated a white scale deposit. This was presumed to be mineral deposits condensing from Rockford Illinois water deposited on the roll through contact with the wet bottom felt. As scaling and sticking were not observed during IPST experiments in Atlanta, samples of Rockford and Atlanta water were analyzed. Table 20 shows an elemental analysis of water samples from both locations showing a substantial difference in dissolved solids.

To characterize the white deposit, scrapings were taken from the Ceramic Coated roll for chemical analysis at the Sandia Nation Laboratory. The results of that analysis showed that the white scale was Calcium Carbonate with trace amounts of other substances. .

As of the writing of this report the participation of the Calcium Carbonate scale in the sticking problem has not been verified. Work to understand the mechanism of sticking is currently ongoing at the Institute.

Table 20. Elemental Analysis of Water Samples from Beloit and Atlanta

Elements	IPST, Atlanta, mg/L	Beloit, Rockford, mg/L
Al	0.04	0.15
Ca	7.3	67.0
Cr	<0.01	0.02
Cu	0.02	<0.01
Fe	0.01	<0.01
K	1.9	0.75
Mg	1.2	33.0
Mn	<0.01	0.03
Na	3.3	3.0
S	2.9	8.8
Si	3.1	6.7
Sn	<0.01	<0.01
Sr	0.02	0.06
Zn	<0.01	<0.01
Zr	0.02	0.01

Review of procedures fused in preparing the ceramic coated roll explain the higher probability of sticking on the drive side of the press roll. Discussions with W. Lenling of Thermal Spray Technologies, Inc. confirm the following regarding the Beloit ceramic coated roll.

1. The Beloit ceramic coated roll had a three layer ceramic coating similar to the IPST roll except that the dense (5% porosity) outer layer was ground to 0.001 inches thick instead of the IPST standard of 0.002 inches thick. In addition, some areas of the inner porous ZrO_2 -Y_2O_3 layer were exposed on one side of the roll.

2. The Beloit ceramic coated roll was ground by Beloit Manhattan. A 120 grit diamond wheel was used followed by hand polishing with a 320 grit silicon carbide paper. The final surface roughness of the Beloit roll ranged from 95-135 Ra with an average of 117 Ra. This was significantly rougher than the IPST roll which was diamond super finished to a 20-40 Ra finish.

Therefore it is hypothesized that surface porosity and or surface smoothness may be important variables controlling sheet sticking.

As an aside, the Beloit Type C roll used on the Beloit X2 ENP was worn prior to running the experiments. The roll typically wears more on the operator side. At the beginning of the experiments the Beloit Type C roll was only about 20% intact; that is, only about 20% of the Beloit Type C surface was actually remaining on the roll prior to the experiments. At the conclusion of the experiments, after operation at 315°C, all of the Beloit Type C surface had been removed from the roll. In contrast, the Beloit Type C roll used for the Beloit roll press experiments was in excellent condition.

CONCLUSIONS

While optimum double felted pressing occurred with the +2 pivot, best impulse drying occurred when the 0 pivot was utilized. Hence, in comparing impulse drying to double felted pressing they should be compared using optimum pivot position and the optimum felts. Table 21 below shows such a comparison of double felted pressing and impulse drying using the Beloit Type C roll surface. All of the data is taken at an impulse of 34 psi seconds using a felt at 0.25 moisture ratio.

Table 21. Impulse Drying and Double Felted Pressing on the Beloit X2 Extended Nip Press at an Impulse of 34 psi seconds

	42% Ingoing Solids						52% Ingoing Solids					
Press Mode	Impulse Drying			Double Felted			Impulse Drying			Double Felt		
Roll Surface	Beloit Roll C			N.A.			Beloit Roll C			N.A.		
Pressure Pivot	0	+2	0	0	+2	0	0	+2	0	0	+2	0
Felt Type	B	B	R	B	B	R	B	B	R	B	B	R
Crit. Temp,°C	148	148	204	N.A.	N.A.	N.A.	204	260	204	N.A.	N.A.	N.A.
%Sout	61.1	61.3	66.4	56.1	56.7	56.6	65.5	65.6	66.0	58.3	60.2	57.8
IPC Density	0.84	0.89	0.87	0.73	0.80	0.78	0.91	0.93	0.88	0.77	0.92	0.77
MDSTFI Index	38.0	36.5	37.9	37.7	34.2	38.7	39.1	37.2	39.4	35.6	38.3	37.0
CD STFI Index	25.8	25.0	26.2	20.5	22.9	25.0	25.3	26.2	25.6	22.8	25.2	23.4
Burst Ind.(WS)	4.42	4.40	5.11	4.00	4.72	3.95	4.35	3.94	5.02	4.18	4.44	4.13
Burst Ind.(FS)	3.94	4.33	4.94	4.09	4.72	3.85	4.26	5.09	5.05	3.40	3.96	3.57

It may be concluded that the choice of felt and pivot position affect sheet strength for both impulse drying and double felted pressing. For a given felt and pivot position, impulse drying yielded higher solids, higher sheet density and higher sheet strength than double felted pressing. Future work should seek to determine optimum pressure pulse shape for a given combination of press roll surface and felt type. Optimum impulse drying at a given impulse should be compared to optimum double felted pressing at the same impulse.

Previously, both Beloit and IPST have conducted impulse drying experiments on slow speed roll presses. In those experiments, long dwell times required for impulse drying are created by operating at low speeds. The pressure versus time history that can be generated by a roll press is limited to that of a haversine, while a shoe press can be configured to achieve a wide range of pressure profiles. The data of the present experiments opens a window of opportunity to compare impulse drying on roll presses and shoe presses where all other variables are kept the same, as shown in Table 22.

Table 22. Roll Presses and Shoe Presses Compared at the Critical Impulse Drying Temperature

	Roll Press Experiment					Shoe Press Experiment					
Press Identity	IPST PILOT				BELOIT HRP	BELOIT X2					
Roll Surface	Ceramic Coated				Roll C	Ceramic Coated				Roll C	
Pressure Pivot	N.A.				N.A.	0	0	0	0	0	2
Felt Type	IPST Standard				B	B	B	B	B	B	B
%Sin	42	52	42	52	42	42	52	42	52	42	42
Impulse, psi sec	16	16	24	24	34	16	16	24	24	34	34
Crit. Temp,°C	350	350	300	300	265	148	260	204	260	148	148
%Sout	60.5	61.1	60.5	61.3	62.2	55.6	56.6	54.0	61.0	61.1	61.3
IPC Density	NM	NM	NM	NM	0.82	0.76	0.76	0.73	0.81	0.84	0.89
MDSTFI Index	30.9	33.8	31.7	31.7	35.7	34.3	35.7	35.7	37.3	38.0	36.5
CD STFI Index	20.1	23.0	20.4	21.4	23.4	22.3	23.6	22.3	23.7	25.8	25.0
Burst Ind.(WS)	3.65	3.87	3.71	3.46	4.14	3.96	3.80	4.73	4.10	4.42	4.40
Burst Ind.(FS)	NM	NM	NM	NM	4.52	3.74	3.84	4.36	3.83	3.94	4.33

For the same cases, Table 23 compares the performance of roll presses to shoe presses at a roll surface temperature of 100°C. All tabulated data was derived from polynomial fits to actual data.

Table 23. Comparison of Roll Presses to Shoe Presses at 100°C

	Roll Press Experiment					Shoe Press Experiment					
Press Identity	IPST PILOT				BELOIT HRP	BELOIT X2					
Roll Surface	Ceramic Coated				Roll C	Ceramic Coated				Roll C	
Pressure Pivot	N.A.				NA	0	0	0	0	0	2
Felt Type	IPST Standard				B	B	B	B	B	B	B
%Sin	42	52	42	52	42	42	52	42	52	42	42
Impulse, psi sec	16	16	24	24	34	16	16	24	24	34	34
Roll Temp,°C	100	100	100	100	100	100	100	100	100	100	100
%Sout	48.3	51.0	52.6	52.5	52.7	54.9	56.7	56.2	58.2	59.5	60.0
IPC Density	NM	NM	NM	NM	0.70	0.80	0.74	0.78	0.78	0.84	0.89
MDSTFI Index	19.8	25.8	28.3	27.0	29.9	34.6	34.1	37.2	35.3	37.2	37.8
CD STFI Index	12.9	16.4	18.1	18.2	19.1	22.7	23.0	24.2	22.7	25.6	25.5
Burst Ind.(WS)	2.68	2.82	3.02	2.57	3.35	3.78	3.71	5.22	3.78	4.47	4.67
Burst Ind.(FS)	NM	NM	NM	NM	3.53	3.36	3.30	4.57	3.52	3.98	4.23

A consistent trend was observed in comparing shoe press and roll press data. In all cases the shoe press resulted in lower critical impulse drying temperature and lower dryness but yielded higher strength even at these lower roll surface temperatures. Examining data at low roll temperatures of 100°C showed that the roll press typically yielded lower dryness and strength than the shoe press. Hence, the roll press exhibits a much steeper temperature dependency than the shoe press.

Review of the present data shows that Impulse Drying can provide significantly higher outgoing solids than double felted pressing at the same impulse. At an impulse of 0.234 MPa seconds (34 psi seconds) sheets at an ingoing solids of 52% can be impulse dried to 68% solids while optimized double felted pressing, at the same impulse, can only yield press dryness of at most 60%. Enhanced press dryness is important in terms of evaporative energy savings and paper machine productivity improvements. Linerboard manufacturers are also interested in the potential to increase sheet physical properties. When the sheets of this study were conventionally pressed to 52% solids and dried they exhibited a geometric mean STFI compression index of 25.9 N m/g and a mean Burst index of 3.0 kPa m^2/g. Similar sheets, pressed from 52% to 60% solids in a double felted extended nip press exhibited an increase in STFI Index of 19.6% and an increase in Burst index of 40%. Sheets impulse dried from 52% solids to 68% solids yielded additional STFI and Burst index increases, over double felted pressing, of 3% and 17% respectively. Hence, impulse drying can be expected to yield substantial press dryness advantages with a small additional physical property improvement.

Two additional accomplishments of the experiments were to demonstrate that the ceramic coated roll could be effectively and safely heated using induction heating and that press felts could survive long term contact with a ceramic roll heated to temperatures of about 315°C.

RECOMMENDATIONS

Previous IPST laboratory scale simulations have suggested that outgoing solids would be independent of roll surface properties at fixed ingoing sheet temperature, pressure profile and roll surface temperature. Roll press impulse drying work using with the Beloit Roll C and Ceramic roll were consistent with this previous result. However, shoe press data showed lower outgoing solids from the Ceramic roll than the Beloit Roll C at similar roll temperatures and impulse. This result needs to be verified in laboratory scale experiments where the influence of pressure pulse shape can be systematically explored.

Low speed roll press impulse drying data suggests a substantial improvement in physical properties with increasing roll temperature. High speed shoe press impulse drying experiments shows a much less steep property increase with roll temperature. This may again be related to the shape of the pressure pulse or may result from release issues that can only be understood by running continuous sheet experiments.

Review of the physical property data shows that strength improvement began to level off with increased impulse and with increased roll surface temperature in the case of impulse drying. The influence of ingoing sheet temperature on the asymptotic strength is presently being investigated in laboratory scale simulations. In addition, the existence of an asymptote needs to be understood.

The slope of the STFI index versus IPC density curve for the X1 shoe press is measurably higher than for the X2 shoe press. The relative flatness of the X2 curve may explain why increasing roll temperature increased sheet density without a substantially increasing sheet strength. Work is underway to investigate whether lower ingoing sheet temperature for X2 caused the drop in slope of the strength versus density curve.

In the present experiments, sticking was not observed in low speed continuous roll press impulse drying simulations but was observed for sheet fed impulse drying experiments on the Beloit extended nip press. Both the Beloit Type C and Ceramic coated press rolls experienced sheet sticking that resulted in complete attachment to the roll surface in one extreme or surface picking at the other extreme. In general, sticking was more severe on the Ceramic surface than the Beloit Type C surface. The fact that sticking was more likely to occur on one side of the Ceramic roll and the fact that the roll was incorrectly ground to have a more porous side, suggests that surface porosity is at least partially responsible. The influence of high concentrations of Calcium and the flash formation of Calcium Carbonate on sticking must also be understood. Once these issues have been explored in laboratory-scale work, a Beloit roll should be re-coated with a correct ceramic surface for repeat of the shoe press impulse drying experiments conducted in this study.

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David Orloff 8/31/92
David I. Orloff
Professor Of Engineering

APPENDIX

Impulse Drying
Results From Ceramic Coated Roll Operated On The Beloit X2 Shoe Press

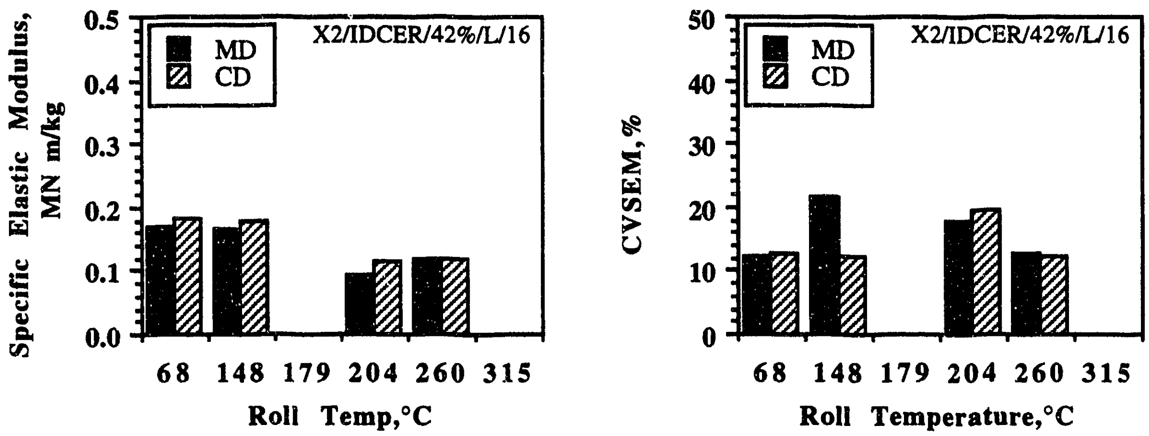

Figure A1. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 42% Ingoing Solids, Low Felt Moisture, 16 psi second Impulse, Steam Pre Heating On.

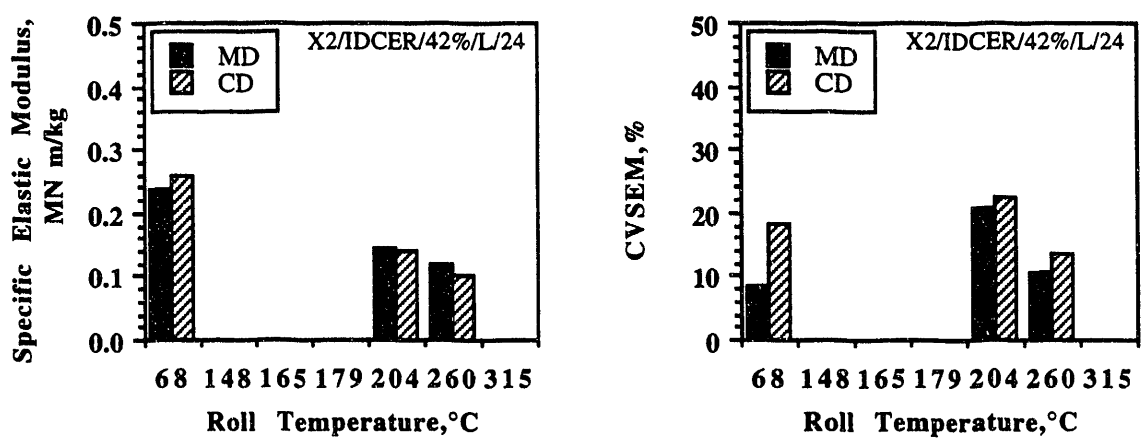

Figure A2. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 42% Ingoing Solids, Low Felt Moisture, 24 psi second Impulse, Steam Pre Heating On.

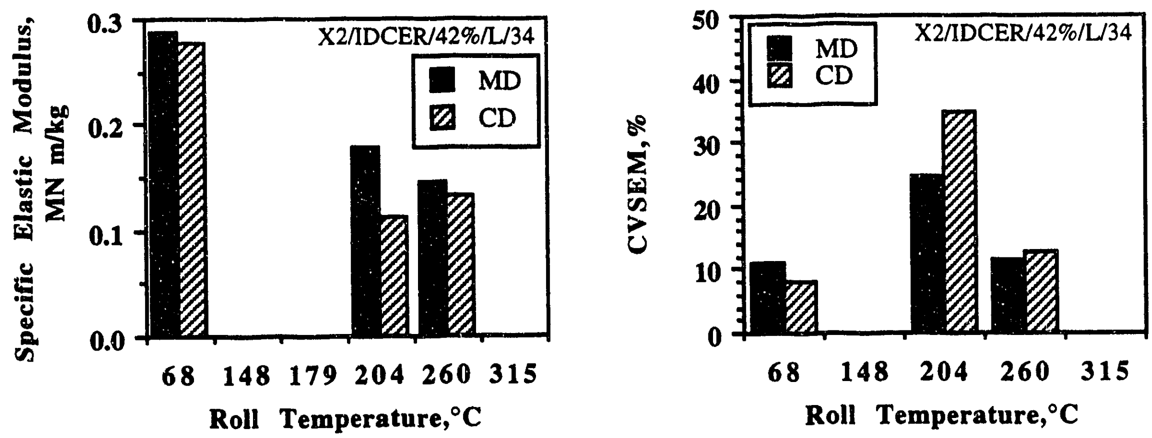

Figure A3. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 42% Ingoing Solids, Low Felt Moisture, 34 psi second Impulse, Steam Pre Heating On.

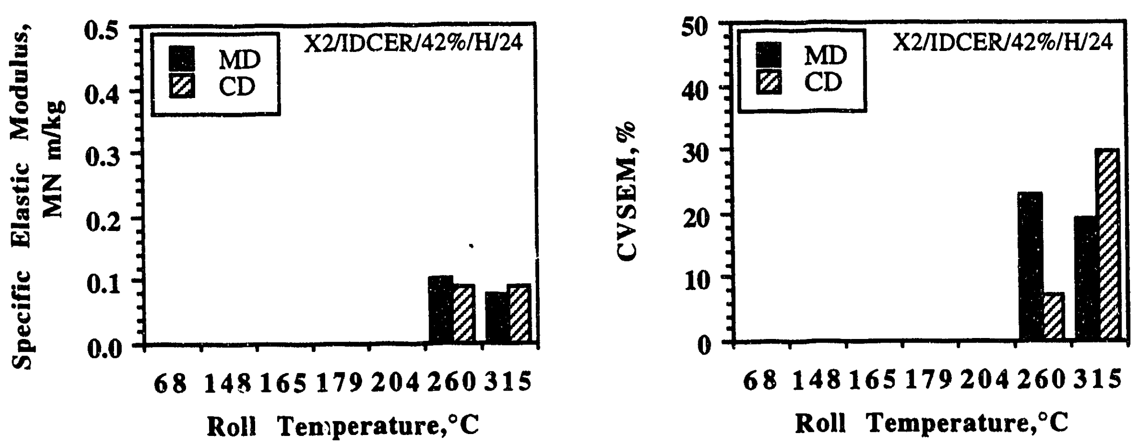

Figure A4. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 42% Ingoing Solids, High Felt Moisture, 24 psi second Impulse, Steam Pre Heating On.

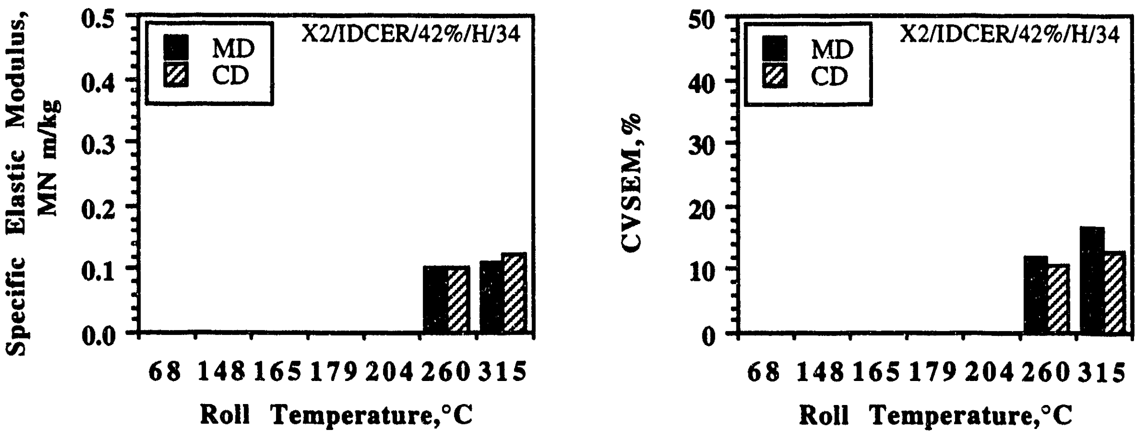

Figure A5. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 42% Ingoing Solids, High Felt Moisture, 34 psi second Impulse, Steam Pre Heating On.

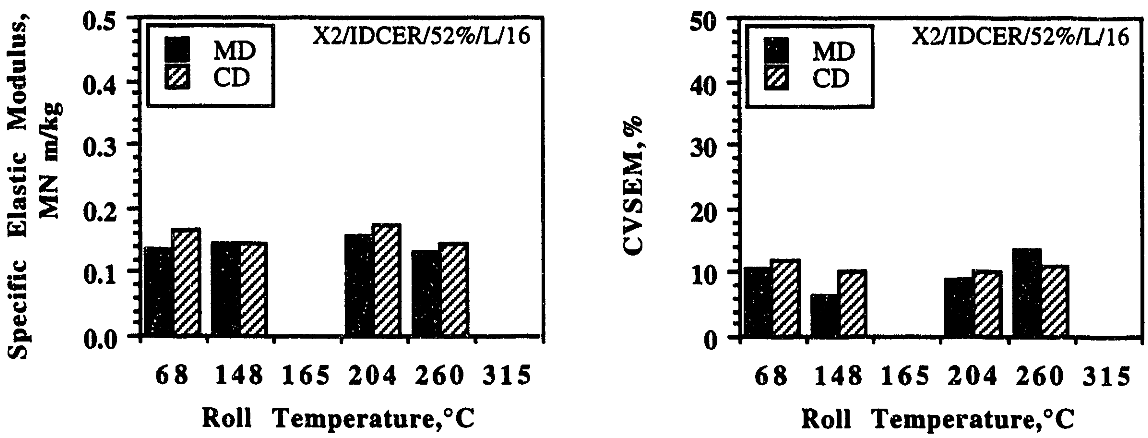

Figure A6. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 52% Ingoing Solids, Low Felt Moisture, 16 psi second Impulse, Steam Pre Heating On.

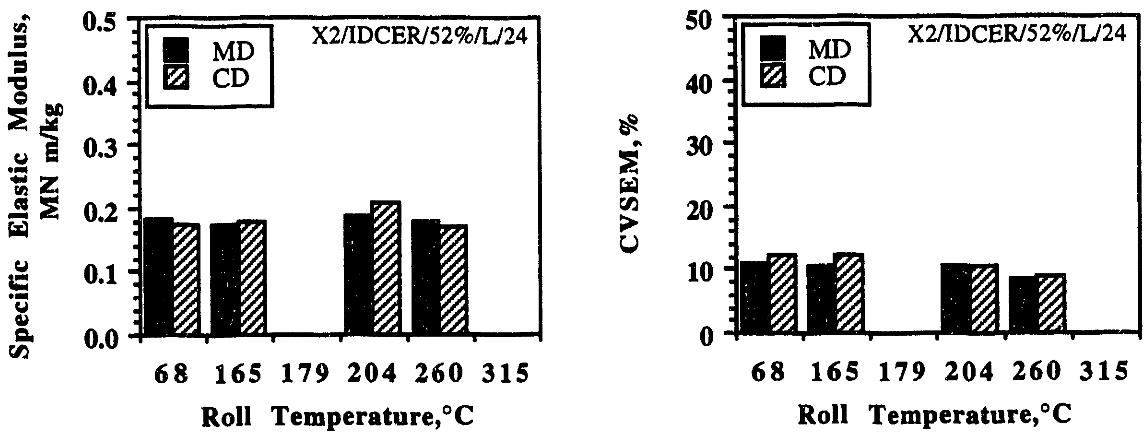

Figure A7. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 52% Ingoing Solids, Low Felt Moisture, 24 psi second Impulse, Steam Pre Heating On.

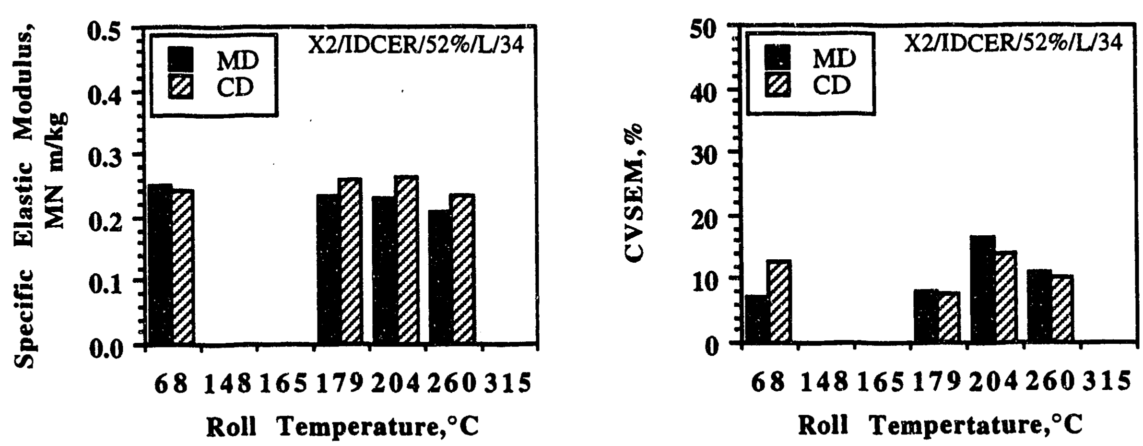

Figure A8. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 52% Ingoing Solids, Low Felt Moisture, 34 psi second Impulse, Steam Pre Heating On.

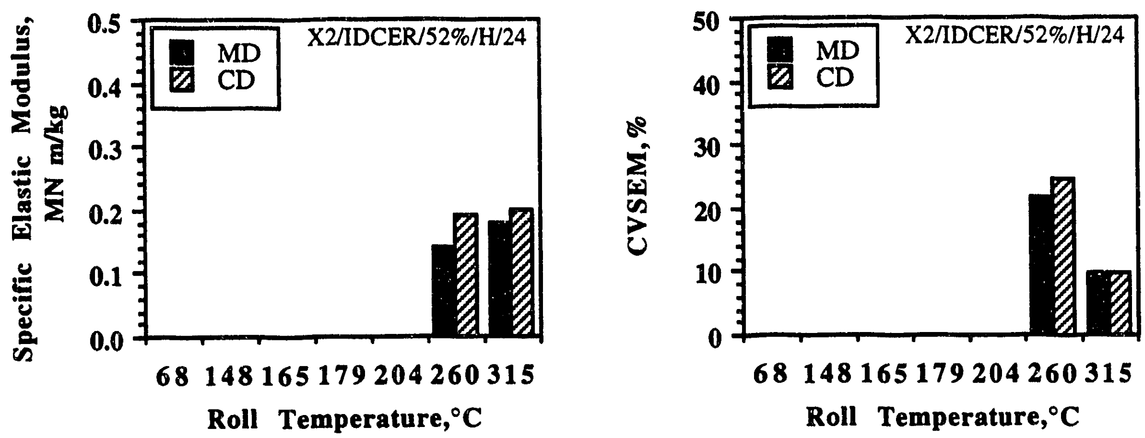

Figure A9. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 52% Ingoing Solids, High Felt Moisture, 24 psi second Impulse, Steam Pre Heating On.

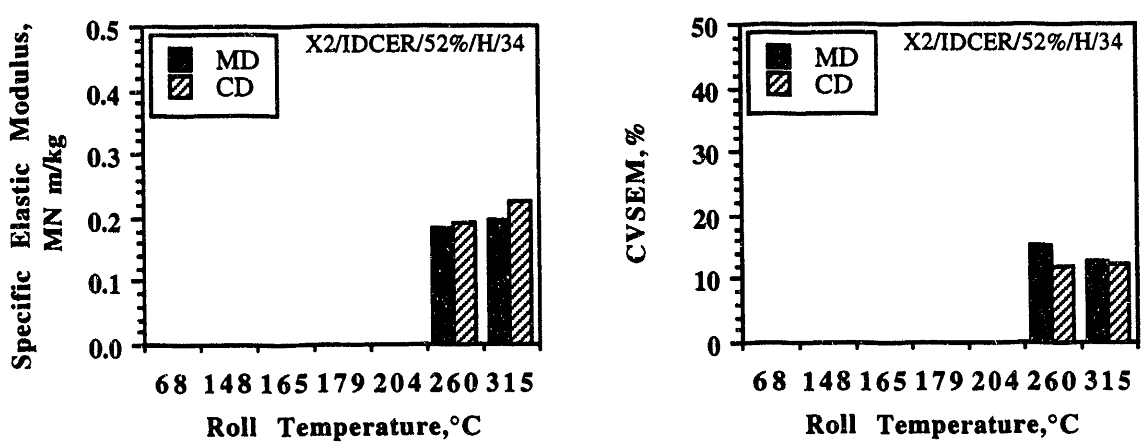

Figure A10. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature For Impulse Drying with a Ceramic Coated Roll on the Beloit X2 Shoe Press. 52% Ingoing Solids, High Felt Moisture, 34 psi second Impulse, Steam Pre Heating On.

Impulse Drying
Results From Beloit Roll C Operated On The Beloit X2 Shoe Press

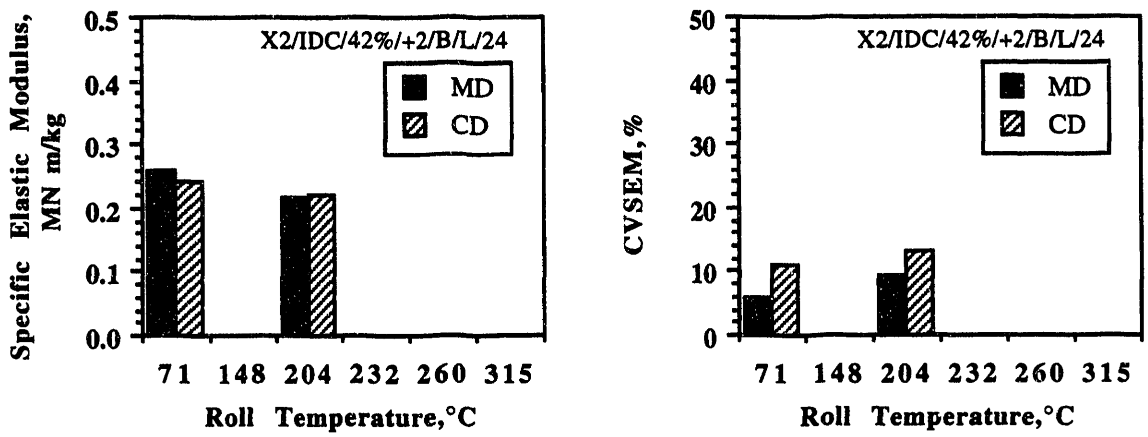

Figure A11. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 42% Ingoing Solids, +2 Pivot, Felt B, Low Felt Moisture, 24 psi second Impulse.

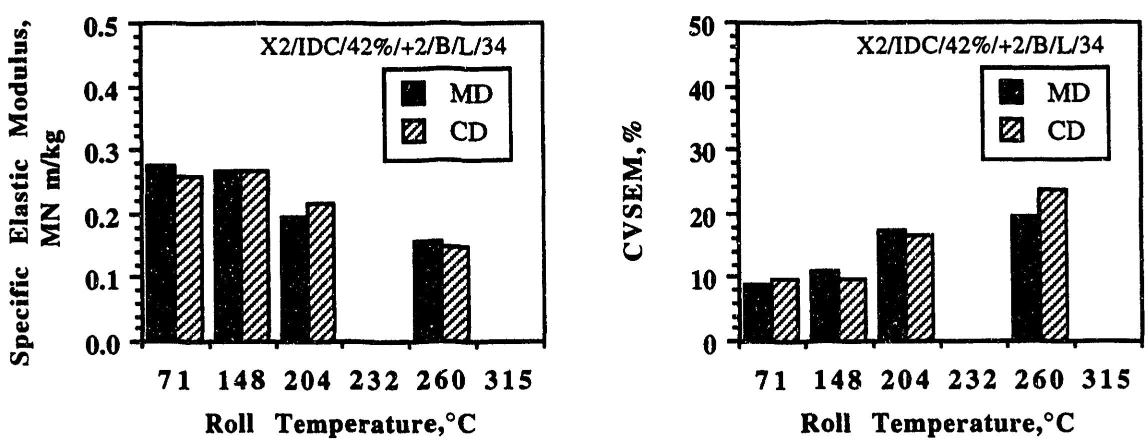

Figure A12. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 42% Ingoing Solids, +2 Pivot, Felt B, Low Felt Moisture, 34 psi second Impulse.

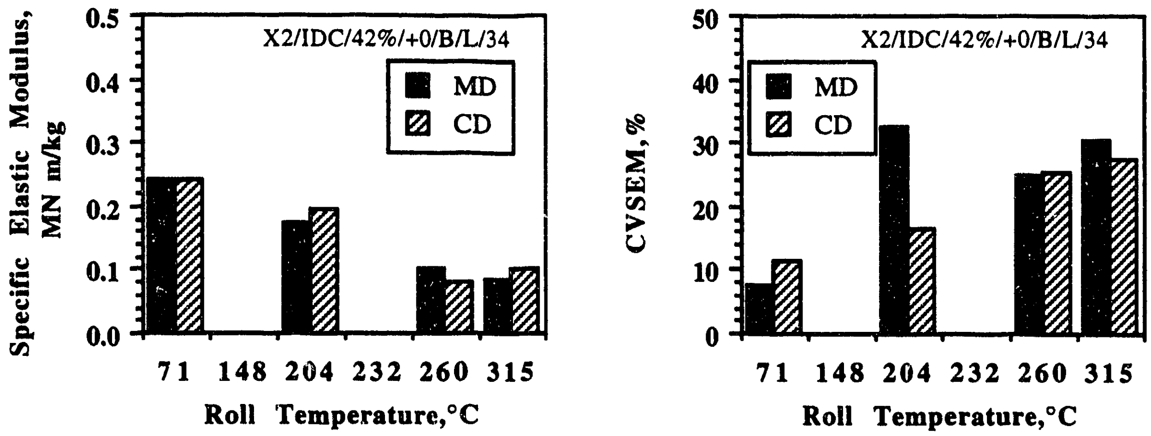

Figure A13. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 42% Ingoing Solids, 0 Pivot, Felt B, Low Felt Moisture, 34 psi second Impulse.

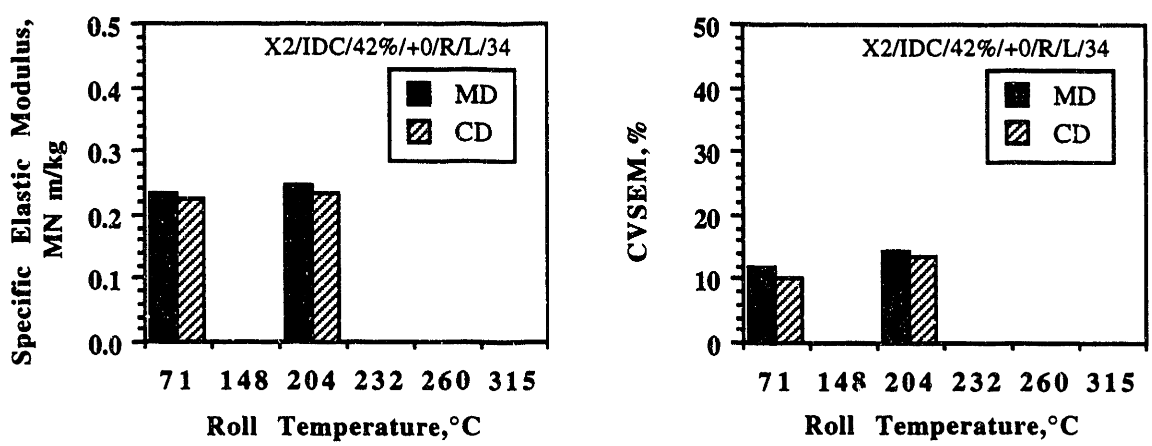

Figure A14. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 42% Ingoing Solids, 0 Pivot, Felt R, Low Felt Moisture, 34 psi second Impulse.

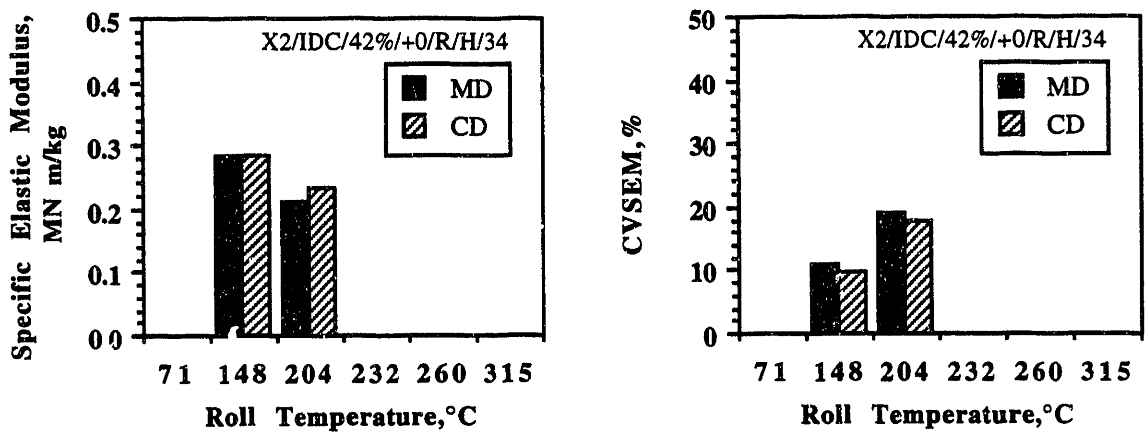

Figure A15. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 42% Ingoing Solids, 0 Pivot, Felt R, High Felt Moisture, 34 psi second Impulse.

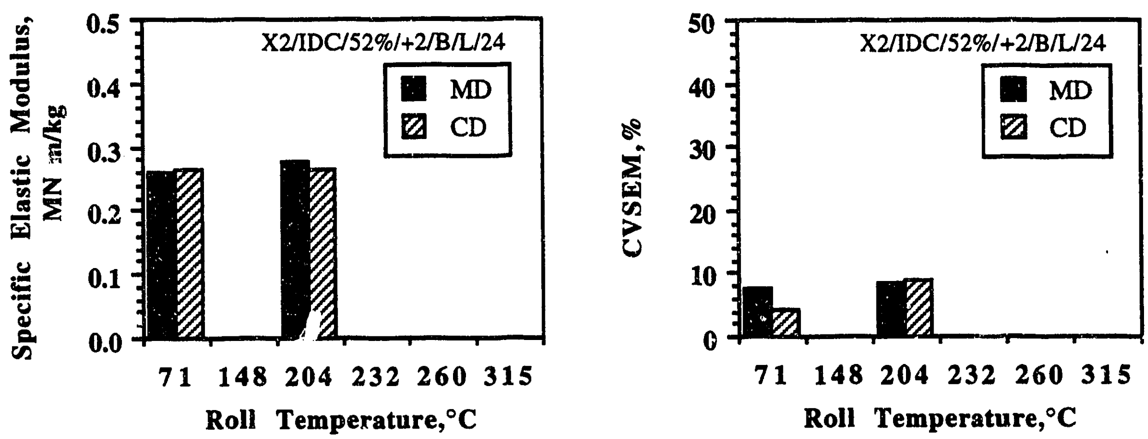

Figure A16. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 52% Ingoing Solids, +2 Pivot, Felt B, Low Felt Moisture, 24 psi second Impulse.

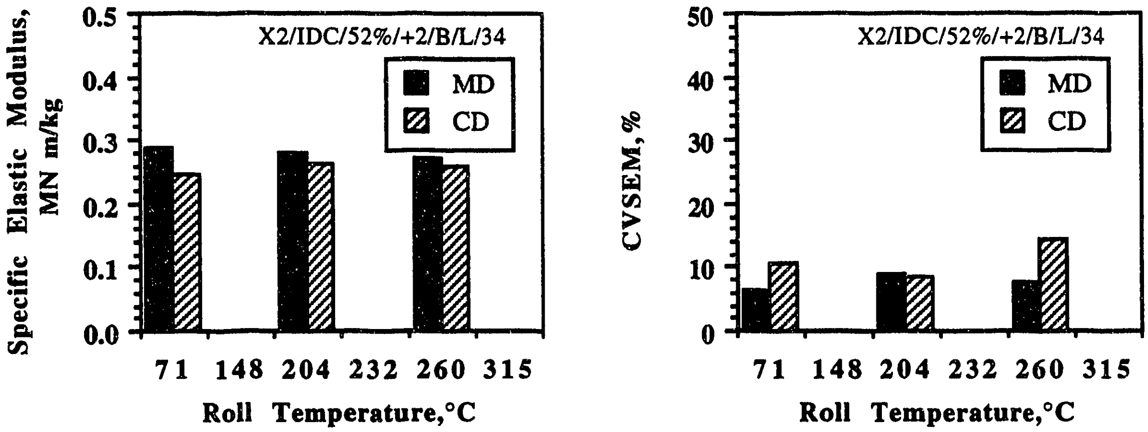

Figure A17. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 52% Ingoing Solids, +2 Pivot, Felt B, Low Felt Moisture, 34 psi second Impulse.

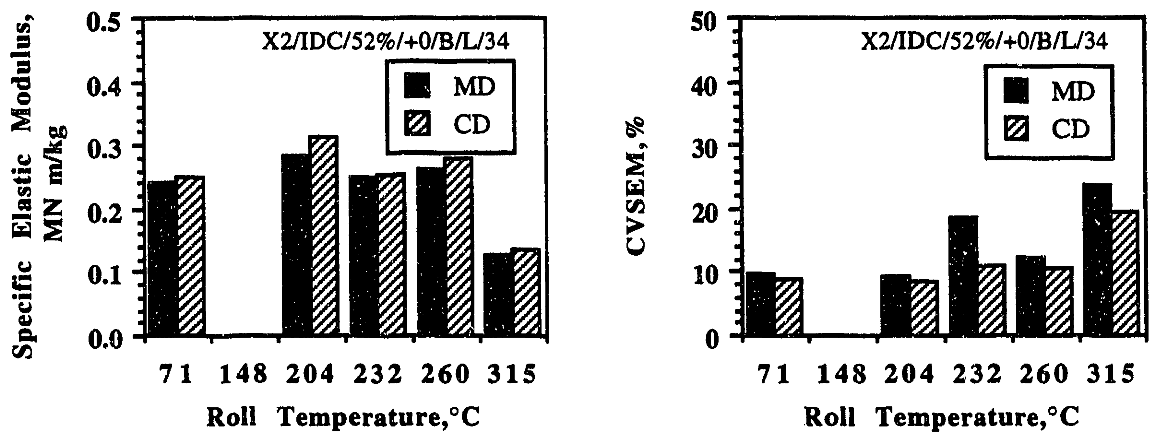

Figure A18. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 52% Ingoing Solids, 0 Pivot, Felt B, Low Felt Moisture, 34 psi second Impulse.

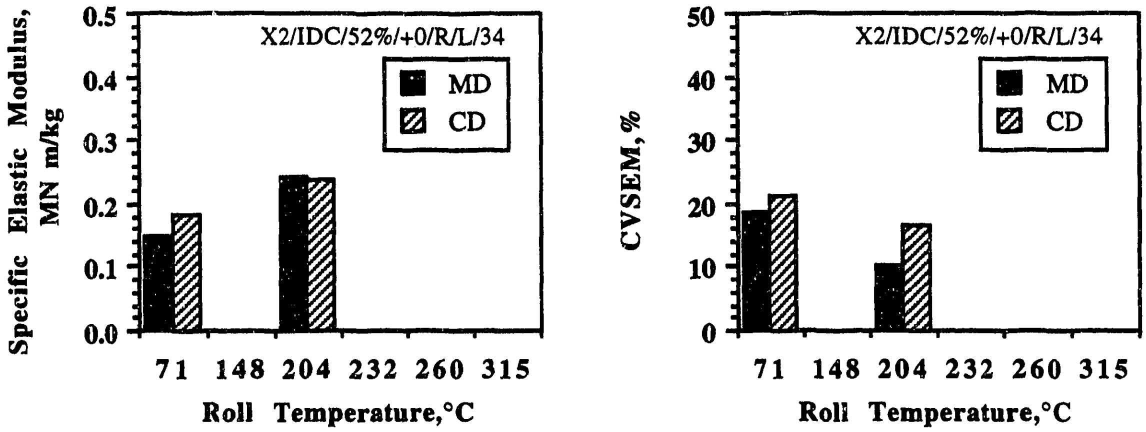

Figure A19. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 52% Ingoing Solids, 0 Pivot, Felt R, Low Felt Moisture, 34 psi second Impulse.

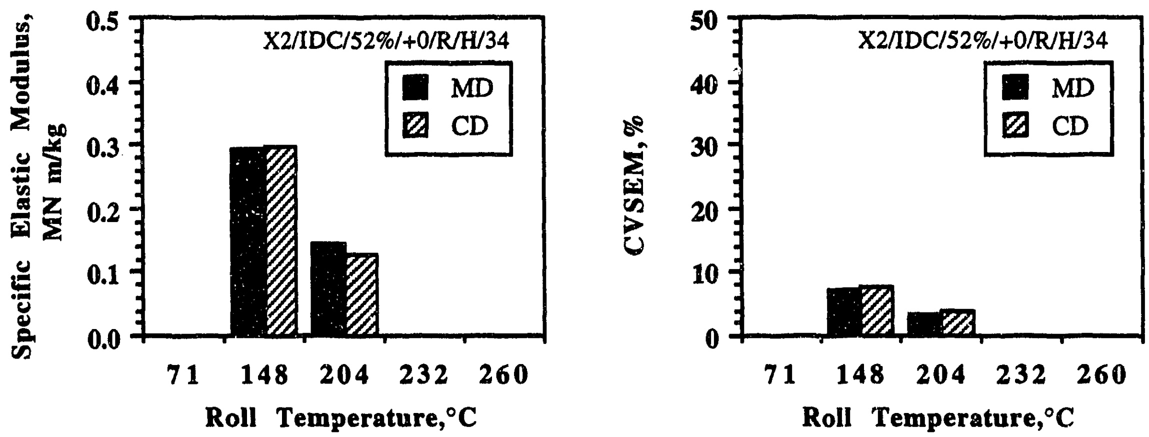

Figure A20. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit Roll C on the Beloit X2 Shoe Press. 52% Ingoing Solids, 0 Pivot, Felt R, High Felt Moisture, 34 psi second Impulse.

Impulse Drying
Results From Ceramic Coated Roll Operated On The IPST Pilot Roll Press

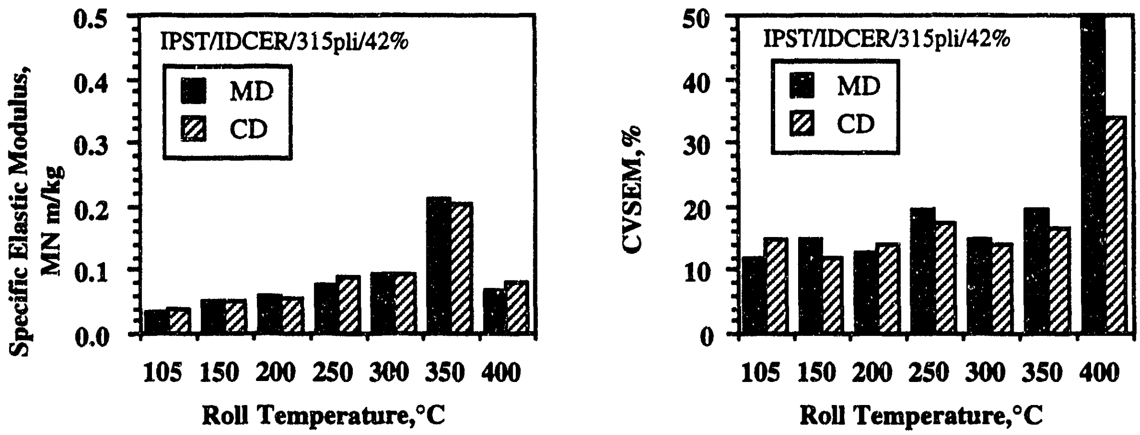

Figure A21. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the IPST Pilot Roll Press. 42% Ingoing Solids, Standard Felt, 16 psi second Impulse, Low Felt Moisture.

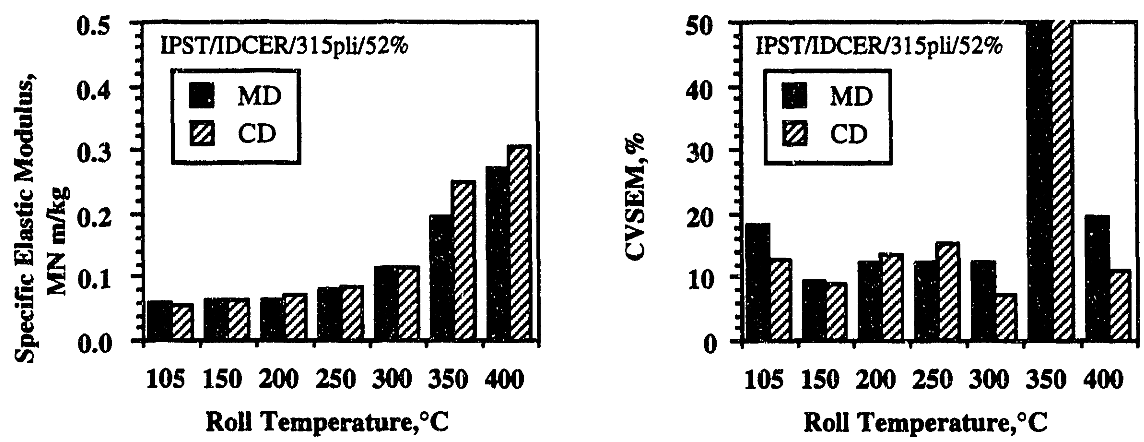

Figure A22. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the IPST Pilot Roll Press. 52% Ingoing Solids, Standard Felt, 16 psi second Impulse, Low Felt Moisture.

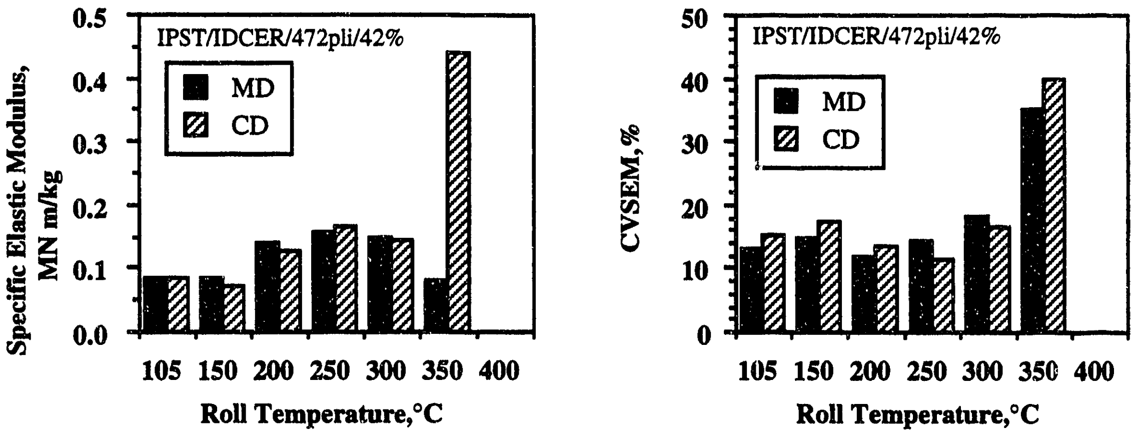

Figure A23. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the IPST Pilot Roll Press. 42% Ingoing Solids, Standard Felt, 24 psi second Impulse, Low Felt Moisture.

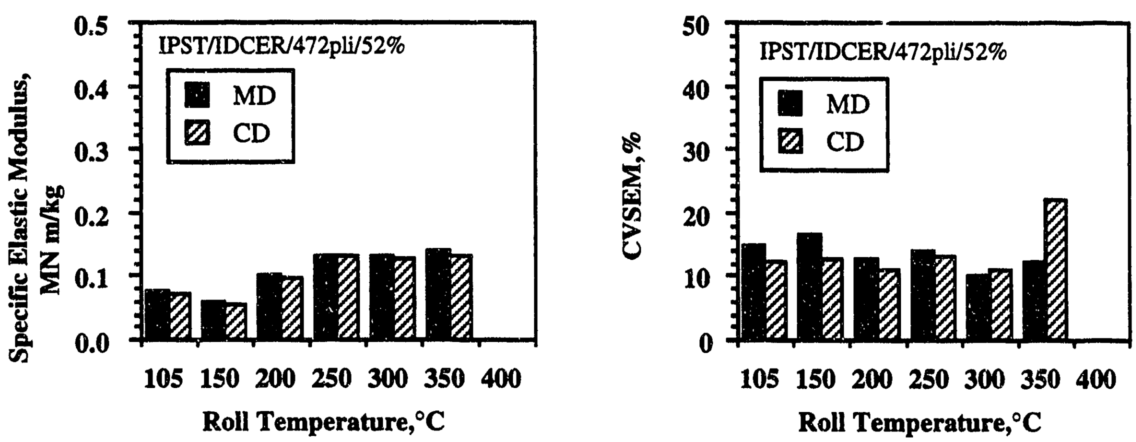

Figure A24. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Ceramic Coated Roll on the IPST Pilot Roll Press. 52% Ingoing Solids, Standard Felt, 24 psi second Impulse, Low Felt Moisture.

Impulse Drying
Results From Beloit "C" Roll Operated On The Beloit HRP Roll Press.

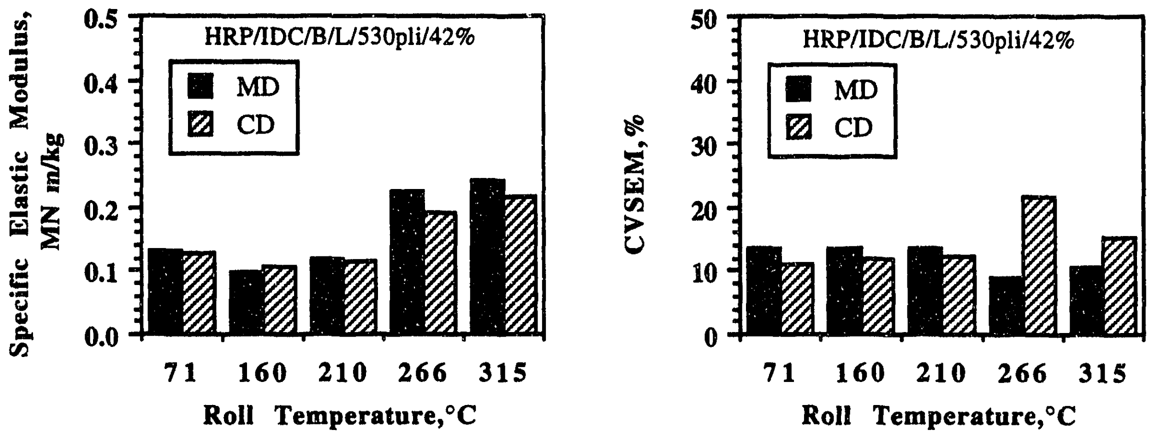

Figure A25. Mean and Coefficient of Variation of the Out-Of-Plane Specific Elastic Modulus as a Function of Roll Surface Temperature for Impulse Drying with a Beloit "C" Roll on the Beloit HRP Roll Press. 42% Ingoing Solids, Felt B, 34 psi second Impulse, Low Felt Moisture.

Table A1 - "Control" Pressed To 42% Solids, Cylinder Dried And Oven Dried

Sample ID	B. Wt. g/m2	Solids %	Burst Ind (WS) kPa·m2/g	Burst Ind (FS) kPa·m2/g	MD STFI Ind N·m/g	CD STFI Ind N·m/g	IPC Density g/cm3
57435.3	205.5	38.2	1.76	2.00	21.66	15.59	0.42
57435.5	219.2	39.0	2.34	1.87	20.57	15.12	0.41
57436.4	232.0	39.6	2.27	1.67	20.38	11.96	0.39
57436.5	220.6	39.9	1.92	1.64	20.65	12.05	0.40
57436.2	212.6	40.0	1.68	1.62	20.64	12.23	0.41
57432.1	215.3	40.5	3.34	2.25	22.81	14.13	0.42
57435.4	219.7	40.7	2.32	1.98	23.25	14.40	0.42
57433.4	181.4	40.8	2.02	1.87	22.21	13.53	0.43
57436.1	224.2	40.8	1.85	2.03	20.83	12.08	0.40
57434.4	191.5	40.9	2.30	1.88	22.33	12.86	0.42
57435.1	222.4	40.9	2.40	2.11	23.80	15.57	0.44
57436.3	233.0	41.0	1.93	1.90	19.59	12.11	0.40
57431.4	200.9	41.0	1.51	2.01	22.32	13.02	0.43
57433.1	200.6	41.1	2.05	1.98	22.33	14.15	0.44
57431.5	246.1	41.1	2.32	1.58	23.08	12.81	0.42
57433.5	196.2	41.1	2.34	2.08	20.53	13.15	0.41
57431.2	207.3	41.1	2.61	2.07	21.22	13.51	0.43
57432.2	209.9	41.1	2.71	2.31	23.50	14.49	0.44
57431.3	204.6	41.2	1.94	1.84	21.77	12.76	0.42
57434.1	193.3	41.2	2.16	2.44	23.15	13.23	0.43
57430.2	200.7	41.3	2.35	1.87	24.53	13.73	0.45
57438.1	224.1	41.3	2.17	1.74	21.25	12.96	0.43
57437.1	212.5	41.4	2.11	1.96	21.92	13.59	0.44
57437.2	238.3	41.4	2.28	2.07	22.29	12.87	0.43
57438.4	224.6	41.4	1.62	1.65	19.43	11.64	0.43
57431.1	240.3	41.5	1.92	1.81	21.19	12.87	0.42
57434.2	211.8	41.5	2.29	2.23	24.86	13.79	0.46
57437.3	217.4	41.6	1.69	1.69	21.50	13.58	0.43
57438.2	199.4	41.6	2.14	2.31	21.72	13.29	0.43
57438.5	229.3	41.7	1.80	1.74	20.48	11.70	0.40
57433.3	196.6	41.9	2.05	1.91	23.25	12.97	0.44
57437.4	223.6	41.9	2.07	2.04	20.90	12.56	0.42
57434.3	205.0	42.0	2.54	1.89	22.94	14.47	0.45
57434.5	199.4	42.1	2.28	1.81	24.07	14.00	0.44
57432.4	219.4	42.3	2.70	1.63	22.86	12.38	0.41
57433.2	190.3	42.4	1.93	1.86	24.23	13.18	0.47
57439.5	208.2	42.4	2.26	1.71	21.49	12.40	0.42
57439.2	212.8	42.4	1.77	1.97	22.69	12.86	0.42
57430.3	195.3	42.6	2.07	1.97	22.82	13.11	0.43

Table A2-Control Pressed To 42% Solids, Cylinder Dried And Oven Dried

Sample ID	B. Wt. g/m^2	Solids %	Burst Ind (WS) kPa·m^2/g	Burst Ind (FS) kPa·m^2/g	MD STFI Ind N·m/g	CD STFI Ind N·m/g	IPC Density g/cm^3
57437.5	241.4	42.8	1.80	2.03	19.99	11.83	0.40
57438.3	201.2	42.8	1.72	1.65	20.40	12.54	0.41
57432.5	227.6	43.1	2.27	2.23	22.63	15.29	0.43
57435.2	216.2	43.1	2.31	2.19	23.97	14.77	0.44
57439.1	202.0	43.2	2.74	2.28	21.74	13.37	0.43
57439.4	197.7	43.2	2.50	1.83	21.49	13.16	0.42
57430.5	194.1	43.3	2.14	2.21	21.99	13.57	0.42
57440.4	204.8	43.7	1.67	2.00	21.33	13.42	0.43
57430.1	193.3	43.9	2.33	2.27	23.33	14.16	0.45
57430.4	199.5	44.0	2.16	2.16	24.13	13.65	0.45
57440.2	184.5	44.1	2.04	1.45	22.30	12.78	0.43
57440.5	209.2	44.4	2.01	1.66	22.09	12.46	0.43
57432.3	213.5	44.8	2.75	2.59	22.99	15.33	0.44
57440.3	223.6	44.8	2.03	1.81	22.29	12.97	0.44
57439.3	220.9	44.9	2.01	1.69	20.45	10.59	0.39
57440.1	222.3	47.2	1.72	1.82	20.09	12.83	0.44

Table A2 -Double Felted Pressing On The X1 Shoe Press From 42% Solids

Sample ID	Pivot	Felt MR	Press Load pli	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Index (WS) $kPa{\cdot}m^2/g$	Burst Index (FS) $kPa{\cdot}m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3
57286.1	-1	L	4000	221.6	47.3	53.6	3.08	2.66	31.78	20.60	0.63
57286.2	-1	L	4000	228.0	44.0	53.0	2.55	2.49	30.68	20.37	0.65
57286.3	-1	L	4000	205.7	44.9	52.4	3.04	2.34	31.11	18.86	0.61
57286.4	-1	L	4000	207.3	43.7	53.0	2.95	2.27	32.03	20.13	0.62
57286.5	-1	L	4000	205.9	42.5	52.7	2.86	1.65	32.43	20.84	0.64
57287.1	-1	L	6000	207.2	42.4	54.4	3.07	3.36	38.35	22.90	0.74
57287.2	-1	L	6000	214.9	42.4	54.9	3.07	2.49	34.59	22.56	0.74
57287.3	-1	L	6000	235.6	42.0	54.9	2.97	2.67	34.08	23.01	0.75
57287.4	-1	L	6000	257.5	41.1	55.1	3.59	3.40	34.80	23.83	0.74
57287.5	-1	L	6000	228.9	42.5	54.5	3.09	3.09	34.02	23.25	0.72
57288.1	-1	L	8500	225.3	41.6	56.2	3.72	3.60	39.33	24.55	0.80
57288.2	-1	L	8500	229.7	41.1	55.9	3.50	3.35	37.62	25.33	0.81
57288.3	-1	L	8500	224.0	41.3	56.0	4.82	3.64	38.13	25.38	0.81
57288.4	-1	L	8500	222.8	41.3	56.3	3.77	3.08	41.65	25.66	0.80
57288.5	-1	L	8500	218.4	41.1	55.9	4.17	3.39	42.80	25.74	0.81
57289.1	0	L	4000	191.8	40.8	52.6	3.48	3.09	32.84	19.55	0.65
57289.2	0	L	4000	188.7	41.8	52.9	3.31	2.76	32.89	20.26	0.64
57289.3	0	L	4000	187.0	47.1	53.7	2.72	2.61	32.84	19.65	0.63
57289.4	0	L	4000	196.6	40.9	52.8	3.32	2.69	29.88	19.65	0.65
57289.5	0	L	4000	199.3	40.7	53.1	3.13	2.43	31.51	19.18	0.65
57290.1	0	L	6000	197.1	37.6	54.9	3.70	3.67	37.50	24.94	0.75
57290.2	0	L	6000	194.5	38.9	54.6	3.73	3.13	36.74	22.38	0.73
57290.3	0	L	6000	183.0	39.1	54.5	3.97	3.79	40.16	23.84	0.73
57290.4	0	L	6000	189.2	40.1	54.4	3.90	3.58	38.30	22.95	0.75
57290.5	0	L	6000	188.8	40.3	54.7	3.09	3.20	38.88	23.89	0.74
57291.1	0	L	8500	196.2	44.9	57.8	4.95	4.23	42.06	26.77	0.77
57291.2	0	L	8500	198.6	41.8	57.6	4.16	3.79	36.86	24.94	0.81
57291.3	0	L	8500	188.9	40.7	57.0	3.74	4.31	36.95	23.52	0.79
57291.4	0	L	8500	197.5	40.8	57.6	4.46	3.69	37.59	25.49	0.80
57291.5	0	L	8500	202.8	41.4	57.8	3.57	3.47	38.88	25.55	0.79

Table A3-Double Felted Pressing On The X1 Shoe Press From 42% Solids

Sample ID	Pivot	Felt MR	Press Load pli	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Index (WS) $kPa \cdot m^2/g$	Burst Index (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3
57292.1	+2	L	4000	226.3	41.5	55.9	3.83	3.61	36.83	23.68	0.75
57292.2	+2	L	4000	226.6	41.5	55.0	3.97	3.25	36.09	23.30	0.74
57292.3	+2	L	4000	218.4	41.8	55.3	3.47	3.03	35.86	21.73	0.74
57292.4	+2	L	4000	217.5	43.2	55.6	3.44	2.78	35.76	22.77	0.72
57292.5	+2	L	4000	201.6	46.9	55.9	3.09	3.45	38.52	23.61	0.73
57293.1	+2	L	6000	200.8	46.4	57.6	4.32	4.43	42.55	26.17	0.80
57293.2	+2	L	6000	208.1	46.1	58.0	4.29	3.86	41.88	25.45	0.80
57293.3	+2	L	6000	202.8	46.2	58.5	3.97	3.76	41.78	25.72	0.81
57293.4	+2	L	6000	199.4	46.0	57.7	3.55	4.15	40.76	24.11	0.80
57293.5	+2	L	6000	205.7	46.5	58.1	3.81	3.91	38.71	24.15	0.80
57294.1	+2	L	7300	202.1	46.3	60.1	4.16	4.40	42.83	27.06	0.86
57294.2	+2	L	7300	209.1	46.5	59.3	4.45	4.04	43.62	26.94	0.85
57294.3	+2	L	7300	206.5	47.1	60.0	4.45	4.45	42.43	25.93	0.85
57294.4	+2	L	7300	210.0	46.9	59.6	3.94	3.87	41.84	24.93	0.83
57294.5	+2	L	7300	193.4	45.0	59.5	4.45	4.23	42.74	28.47	0.85

Table A4 - Double Felted Pressing On The X1 Shoe Press From 52% Solids

Sample ID	Pivot	Felt MR	Press Load pli	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Index (WS) $kPa{\cdot}m^2/g$	Burst Index (FS) $kPa{\cdot}m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3
57295.1	-1	L	4000	195.4	53.4	53.8	3.67	2.72	33.70	21.19	0.67
57295.2	-1	L	4000	186.5	53.3	54.2	3.89	2.87	34.02	20.80	0.66
57295.3	-1	L	4000	187.6	54.1	54.3	3.29	2.38	30.88	19.89	0.63
57295.4	-1	L	4000	224.4	53.0	53.5	3.71	3.52	35.57	22.75	0.69
57295.5	-1	L	4000	217.1	52.2	53.3	3.39	3.48	36.06	23.21	0.71
57296.1	-1	L	6000	222.8	52.5	55.4	4.33	3.65	37.58	25.30	0.78
57296.2	-1	L	6000	214.9	52.0	55.3	4.28	3.77	38.45	24.44	0.77
57296.3	-1	L	6000	221.1	51.4	55.6	3.66	3.79	39.29	23.33	0.78
57296.4	-1	L	6000	206.5	50.8	57.1	3.12	3.41	35.07	24.65	0.74
57296.5	-1	L	6000	206.9	51.2	56.7	4.16	3.25	36.09	24.68	0.75
57297.1	-1	L	8500	210.1	51.1	58.9	4.75	5.38	41.90	25.45	0.81
57297.2	-1	L	8500	210.5	51.1	58.4	5.03	4.11	40.49	27.42	0.85
57297.3	-1	L	8500	209.0	51.5	59.0	3.15	4.48	41.01	26.47	0.81
57297.4	-1	L	8500	206.2	51.2	58.4	4.31	4.00	40.90	25.04	0.81
57297.5	-1	L	8500	203.3	51.1	58.2	3.51	4.07	40.64	26.17	0.82
57298.1	0	L	4000	210.7	53.6	55.1	3.47	3.08	33.74	20.97	0.73
57298.2	0	L	4000	207.3	53.2	54.9	4.23	3.26	36.77	21.58	0.71
57298.3	0	L	4000	203.8	53.3	54.8	3.63	2.93	35.34	21.71	0.73
57298.4	0	L	4000	205.7	53.2	54.5	3.62	3.04	36.70	22.14	0.72
57298.5	0	L	4000	207.2	53.1	54.7	3.83	3.08	36.31	22.22	0.72
57299.1	0	L	6000	206.2	53.3	57.0	3.94	3.71	39.93	25.13	0.75
57299.2	0	L	6000	212.3	52.5	56.6	3.56	3.18	37.98	27.50	0.75
57299.3	0	L	6000	214.9	51.9	55.9	3.82	3.56	37.45	27.31	0.76
57299.4	0	L	6000	218.5	52.0	55.9	4.04	2.89	35.96	27.63	0.77
57299.5	0	L	6000	199.5	51.5	55.6	3.95	2.83	36.19	29.02	0.76
57300.1	0	L	8500	210.8	51.8	57.8	3.32	3.07	34.87	28.86	0.82
57300.2	0	L	8500	227.3	52.3	58.0	4.02	3.27	37.57	29.90	0.81
57300.3	0	L	8500	215.2	52.4	57.8	2.95	3.15	33.91	29.83	0.81
57300.4	0	L	8500	213.4	52.2	57.6	3.73	3.56	42.00	27.87	0.82
57300.5	0	L	8500	237.7	52.4	57.3	3.39	3.79	36.77	26.86	0.84

Table A5 -Double Felted Pressing On The X1 Shoe Press From 52% Solids

Sample ID	Pivot	Felt MR	Press Load pli	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Index (WS) $kPa \cdot m^2/g$	Burst Index (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3
57301.1	+2	L	4000	202.9	50.9	56.6	3.85	3.48	38.02	23.40	0.75
57301.2	+2	L	4000	202.9	51.0	56.6	3.09	3.26	37.87	23.17	0.75
57301.3	+2	L	4000	204.2	51.3	56.4	3.80	2.40	35.93	22.97	0.74
57301.4	+2	L	4000	197.8	51.1	56.1	3.66	3.80	39.52	24.83	0.75
57301.5	+2	L	4000	193.1	51.4	56.7	3.65	3.28	37.92	23.71	0.76
57302.1	+2	L	6000	201.5	51.4	58.7	3.73	3.73	41.63	25.38	0.82
57302.2	+2	L	6000	205.7	51.0	58.0	4.11	3.44	40.98	26.15	0.80
57302.3	+2	L	6000	195.1	51.0	58.1	5.31	3.33	41.74	27.05	0.82
57302.4	+2	L	6000	214.1	50.8	57.4	4.86	3.68	44.02	27.55	0.83
57302.5	+2	L	6000	224.1	50.8	57.8	4.39	4.08	44.24	28.63	0.82
57303.1	+2	L	7300	217.9	50.4	58.4	5.44	4.27	49.03	28.83	0.87
57303.2	+2	L	7300	220.5	50.7	58.8	4.01	3.82	45.39	29.04	0.86
57303.3	+2	L	7300	221.5	50.9	58.2	4.93	3.70	43.91	29.12	0.86
57303.4	+2	L	7300	220.0	51.0	59.0	5.00	4.33	47.82	29.16	0.85
57303.5	+2	L	7300	222.6	51.2	58.7	5.39	4.16	40.65	27.35	0.85

Table A6- Double Felted Pressing On The X2 Shoe Press From 42% Solids

Sample ID	Pivot	Bottom Felt	Felt MR	Press Load pli	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind (WS) $kPa \cdot m^2/g$	Burst Ind (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3
57463.1	0	B	L	6000	202.6	43.8	55.6	4.02	3.20	35.21	19.46	0.71
57463.2	0	B	L	6000	211.4	44.1	56.6	3.77	4.16	34.21	20.02	0.70
57463.3	0	B	L	6000	211.3	43.6	57.6	3.35	4.04	36.27	20.87	0.76
57463.4	0	B	L	6000	212.6	43.3	56.6	5.09	4.09	35.53	22.28	0.74
57463.5	0	B	L	6000	204.3	43.4	55.6	3.92	3.57	30.03	14.60	0.65
57337.1	0	B	L	8500	212.1	43.4	56.6	4.48	4.41	38.57	20.18	0.73
57337.2	0	B	L	8500	194.6	43.4	57.3	4.16	3.53	35.49	21.15	0.75
57337.3	0	B	L	8500	181.8	41.8	52.8	3.77	4.69	34.88	19.58	0.69
57337.4	0	B	L	8500	187.6	41.4	57.1	4.48	3.44	40.72	20.55	0.76
57337.5	0	B	L	8500	194.2	41.1	56.7	3.09	4.39	38.69	21.19	0.72
57448.1	0	B	H	8500	220.9	42.5	55.0	3.43	2.73	31.87	20.25	0.71
57448.2	0	B	H	8500	229.3	41.5	55.5	3.84	3.84	33.34	20.95	0.73
57448.3	0	B	H	8500	222.6	41.2	54.9	3.24	3.33	31.29	20.98	0.69
57448.4	0	B	H	8500	222.8	40.7	53.4	4.26	3.52	32.35	20.99	0.72
57448.5	0	B	H	8500	219.2	42.7	54.6	3.07	3.54	35.45	22.18	0.74
57339.1	+2	B	L	6000	187.1	41.2	56.3	3.40	4.11	41.65	23.97	0.80
57339.2	+2	B	L	6000	191.5	41.5	57.6	4.33	3.97	37.75	23.19	0.81
57339.3	+2	B	L	6000	189.3	41.4	56.2	4.90	4.07	38.31	21.43	0.75
57339.4	+2	B	L	6000	184.5	41.4	55.9	5.12	4.40	37.42	23.40	0.80
57339.5	+2	B	L	6000	184.7	42.4	56.1	4.15	3.13	38.80	22.90	0.66
57341.1	+2	B	L	8500	209.2	43.8	56.6	4.95	4.69	37.93	23.30	0.82
57341.2	+2	B	L	8500	204.6	43.1		4.05	4.67	27.28	17.96	0.71
57341.3	+2	B	L	8500	183.0	42.7	54.3	5.00	4.80	33.83	24.76	0.80
57341.4	+2	B	L	8500	212.8	42.8	58.2	4.46	4.13	36.50	25.50	0.84
57341.5	+2	B	L	8500	190.3	43.4	57.6	5.14	5.33	35.39	22.71	0.85

Table A7 - Double Felted Pressing On The X2 Shoe Press From 42% Solids

Sample ID	Pivot	Bottom Felt	Felt MR	Press Load pli	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind (WS) $kPa \cdot m^2/g$	Burst Ind (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3
57378.1	0	R	L	6000	201.1	34.0	54.3	3.40	3.46	32.77	22.57	0.75
57378.2	0	R	L	6000								
57378.3	0	R	L	6000	206.1	40.4	55.5	4.35	3.32	37.35	24.63	0.79
57378.4	0	R	L	6000	202.2	41.1	56.3	3.73	3.56	37.45	24.24	0.79
57378.5	0	R	L	6000	215.8	41.7	55.0	4.12	3.90	36.92	23.06	0.75
57460.1	0	R	L	8500	209.0	42.6	56.6	3.70	4.12	39.83	25.48	0.80
57460.2	0	R	L	8500	214.1	42.5	56.3	3.68	3.52	39.37	23.70	0.77
57460.3	0	R	L	8500	209.1	42.9	55.9	3.65	3.81	39.21	24.61	0.77
57460.4	0	R	L	8500	213.4	43.6	56.8	4.13	3.94	37.96	24.56	0.77
57460.5	0	R	L	8500	212.1	43.7	57.7	4.60	3.84	36.93	26.90	0.79

Table A8- Double Felted Pressing On The X2 Shoe Press From 52% Solids

Sample ID	Pivot	Bottom Felt	Felt MR	Press Load pli	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind (WS) kPa·m^2/g	Burst Ind (FS) kPa·m^2/g	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3
57464.1	0	B	L	6000	208.1	52.7	57.8	4.12	3.30	35.42	22.96	0.75
57464.2	0	B	L	6000	203.0	51.7	57.4	3.44	3.98	37.32	20.34	0.72
57464.3	0	B	L	6000	209.5	52.4	58.2	4.22	3.61	34.61	21.07	0.74
57464.4	0	B	L	6000	199.7	51.8	57.0	2.57	3.25	32.73	20.54	0.72
57464.5	0	B	L	6000	209.2	52.2	57.2	4.07	4.27	36.32	22.55	0.76
57338.1	0	B	L	8500	208.1	52.7	58.6	4.87	3.48	34.20	23.75	0.80
57338.2	0	B	L	8500	205.5	52.5	57.8	4.78	2.66	37.16	22.30	0.77
57338.3	0	B	L	8500	223.6	52.6	59.9	3.83	3.35	36.89	23.96	0.79
57338.4	0	B	L	8500	233.4	53.0	57.5	4.04	2.95	35.54	23.37	0.75
57338.5	0	B	L	8500	232.5	52.9	58.7	3.47	3.67	33.23	20.73	0.77
57449.1	0	B	H	8500	233.3	54.2	58.9	3.99	3.12	34.96	23.99	0.78
57449.2	0	B	H	8500	210.3	54.1	58.5	4.66	3.68	38.98	22.01	0.75
57449.3	0	B	H	8500	199.7	54.0	58.4	4.05	3.35	41.59	19.31	0.77
57449.4	0	B	H	8500	207.6	53.4	58.1	4.22	3.09	37.94	22.41	0.74
57449.5	0	B	H	8500	204.1	53.5	57.8	4.23	3.60	38.12	20.90	0.76
57340.1	+2	B	L	6000	229.9	54.0	57.5	4.14	3.41	34.58	23.02	0.80
57340.2	+2	B	L	6000	228.2	53.5	58.0	3.75	3.58	35.52	23.45	0.79
57340.3	+2	B	L	6000	227.5	53.0	58.6	3.86	4.40	36.16	23.29	0.82
57340.4	+2	B	L	6000	232.8	52.9	58.1	3.90	3.70	36.30	22.79	0.79
57340.5	+2	B	L	6000	226.8	52.9	58.5	3.58	3.60	34.63	23.38	0.81
57342.1	+2	B	L	8500	242.8	53.4	59.9	3.76	3.59	36.76	25.88	0.89
57342.2	+2	B	L	8500	203.9	53.1	59.9	4.74	4.64	41.55	24.34	0.89
57342.3	+2	B	L	8500	207.2	53.5	60.9	5.11	3.98	39.56	26.36	0.95
57342.4	+2	B	L	8500	200.8	53.2	60.0	4.01	3.92	37.30	23.33	0.93
57342.5	+2	B	L	8500	212.5	55.0	60.1	4.56	3.66	36.41	25.93	0.93

Table A9 - Double Felted Pressing On The X2 Shoe Press From 52% Solids

Sample ID	Pivot	Bottom Felt	Felt MR	Press Load pli	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind (WS) $kPa \cdot m^2/g$	Burst Ind (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3
57459.1	0	R	L	6000	234.3	50.9	56.6	3.73	3.16	34.57	22.06	0.74
57459.2	0	R	L	6000	229.4	50.9	57.3	3.81	3.54	35.07	23.24	0.76
57459.3	0	R	L	6000	231.2	50.9	56.5	3.50	3.06	34.34	22.27	0.76
57459.4	0	R	L	6000	228.6	51.0	56.4	4.14	3.49	31.89	22.39	0.73
57459.5	0	R	L	6000	231.7	51.6	57.5	4.06	3.12	34.16	21.76	0.73
57461.1	0	R	L	8500	235.1	51.7	57.7	4.20	4.14	36.17	24.17	0.77
57461.2	0	R	L	8500	232.8	51.5	57.9	3.77	3.80	37.26	23.44	0.79
57461.3	0	R	L	8500	221.3	51.4	57.6	4.21	3.55	36.97	23.47	0.78
57461.4	0	R	L	8500	222.0	51.6	57.9	4.61	3.11	37.70	24.78	0.76
57461.5	0	R	L	8500	205.6	51.8	58.2	3.93	3.67	39.86	22.76	0.79

Table A10-Impulse Drying On The X2 Shoe Press From 42% Solids Using The Beloit "C" Roll, Felt B,"0" Pivot

Sample ID	Pivot	FMR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa·m^2/g$	Burst Ind. (FS) $kPa·m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57447.2	0	L	6000	71		42.1	58.6	3.21	3.52	34.02	21.21	0.82	0.260	6.7	0.220	12.3
57447.3	0	L	6000	71		42.7	59.6	5.72	4.60	35.06	23.54	0.83	0.220	8.5	0.230	12.0
57447.5	0	L	6000	71		46.0	60.6	4.73	3.46	32.47	24.33	0.84	0.250	8.1	0.280	9.4
57345.1	0	L	6000	204		44.0	58.9	3.65	3.97	29.49	21.02	0.79	0.120	46.2	0.120	19.7
57345.2	0	L	6000	204		42.2	63.5	5.43	5.46	38.41	25.51	0.88	0.270	8.9	0.260	6.5
57345.3	0	L	8500	204		41.4		3.72	3.43	29.17	19.05	0.75	0.100	26.8	0.100	29.4
57345.4	0	L	8500	204		40.6	62.6	4.78	4.58	36.57	23.31	0.90	0.250	11.8	0.250	6.7
57345.5	0	L	8500	204		40.9	64.2	3.43	3.43	30.60	22.88	0.81	0.120	68.9	0.240	19.7
57347.1	0	L	8500	260		40.3	65.4	4.89	4.06	32.92	22.04	0.82	0.140	29.9	0.140	28.4
57347.2	0	L	8500	260		40.2	65.2	4.11	3.01	25.36	16.76	0.59	0.080	17.3	0.010	15.4
57347.3	0	L	8500	260		40.3	66.6	4.95	4.51	29.01	20.31	0.74	0.120	40.3	0.110	50.5
57347.5	0	L	8500	260		42.0	65.2	4.23	2.91	22.53	17.55	0.57	0.060	12.5	0.060	8.3
57349.3	0	L	8500	316		44.8	66.1	4.27	3.86	34.23	21.62	0.77	0.110	46.8	0.100	38.2
57349.4	0	L	8500	316		42.3	67.1	3.90	3.77	32.26	20.35	0.75	0.070	23.9	0.070	18.9
57349.5	0	L	8500	316		42.9	66.4	4.34	3.81	30.85	22.72	0.79	0.070	21.2	0.140	25.9

Table A11-Impulse Drying On The X2 Shoe Press From 42% Solids Using The Beloit "C" Roll, Felt B,+2 Pivot

Sample ID	Pivot	FMR	Press Load pli	Roll Temp °C	B. Wt. g/m2	Solids In %	Solids Out %	Burst Ind. (WS) kPa·m2/g	Burst Ind. (FS) kPa·m2/g	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57455.2	+2	L	6000	71	222.3	40.7	54.6	4.80	3.95	35.48	23.71	0.83	0.260	7.6	0.230	9.4
57455.3	+2	L	6000	71	235.9	39.8	54.8	4.85	3.58	35.92	23.78	0.79	0.260	4.6	0.250	12.9
57453.1	+2	L	6000	204	198.8	41.7	62.6	4.42	5.00	34.50	23.87	0.88	0.200	8.5	0.210	10.6
57453.2	+2	L	6000	204	208.1	41.1	59.2	4.88	4.94	35.52	24.29	0.86	0.230	12.5	0.250	6.3
57453.3	+2	L	6000	204	203.3	40.8	60.4	4.39	5.06	34.43	22.72	0.84	0.210	9.5	0.190	14.7
57453.4	+2	L	8500	204	217.0	40.8	59.4	3.79	4.36	34.86	24.90	0.85	0.230	9.5	0.260	7.1
57453.5	+2	L	8500	204	214.7	40.9	59.4	4.13	4.72	35.82	23.22	0.85	0.220	6.4	0.190	26.8
57365.1	+2	L	8500	71	218.7	46.0	59.2	4.86	3.73	40.21	25.58	0.87	0.290	11.2	0.260	8.5
57365.2	+2	L	8500	71	227.1	43.8	58.3	4.99	4.17	38.53	25.99	0.85	0.290	7.6	0.270	4.4
57365.3	+2	L	8500	71	213.5	42.7	57.0	4.74	4.30	36.96	25.63	0.83	0.250	7.6	0.240	16.6
57355.1	+2	L	8500	149	220.1	46.0	64.9	4.79	3.97	37.83	24.98	0.88	0.300	7.1	0.270	6.7
57355.2	+2	L	8500	149	225.9	42.8	61.8	4.19	4.38	37.08	26.11	0.92	0.250	12.6	0.290	6.1
57355.3	+2	L	8500	149	208.7	42.0	62.5	4.31	3.94	36.30	23.76	0.91	0.250	7.6	0.230	5.2
57355.4	+2	L	8500	149	222.8	42.4	61.9	3.84	5.13	35.29	26.70	0.91	0.290	6.7	0.290	11.7
57355.5	+2	L	8500	149	223.6	42.9	61.1	4.66	4.24	34.90	23.03	0.88	0.240	20.5	0.260	18.7
57359.1	+2	L	8500	204	214.3	44.2	63.1	3.84	4.81	35.60	24.24	0.87	0.170	13.3	0.210	18.5
57359.2	+2	L	8500	204	195.3	44.1	63.6	4.81	4.85	36.09	23.80	0.85	0.180	29.0	0.170	22.8
57359.3	+2	L	8500	204	204.6	43.8	63.0	3.85	4.42	32.35	24.43	0.88	0.180	28.6	0.230	18.8
57359.4	+2	L	8500	204	191.2	45.9	63.1	3.95	4.58	35.63	24.72	0.91	0.200	8.9	0.200	18.2
57357.1	+2	L	8500	260	226.0	43.8	63.8	4.29	4.26	30.49	22.28	0.83	0.090	9.9	0.100	29.7
57357.2	+2	L	8500	260	221.5	43.2	63.7	3.46	3.93	32.19	21.11	0.83	0.160	34.2	0.110	27.6
57357.3	+2	L	8500	260	216.1	44.9	63.2	3.31	4.33	29.44	22.62	0.82	0.110	41.7	0.140	40.3
57357.4	+2	L	8500	260	217.1	40.8	64.5	3.10	4.99	34.11	24.25	0.85	0.150	15.4	0.150	20.7
57357.5	+2	L	8500	260	217.9	41.9	65.0	4.33	4.39	35.64	21.35	0.81	0.150	12.6	0.120	15.6

Table A12-Impulse Drying On The X2 Shoe Press From 42% Solids Using The Beloit "C" Roll, Felt R, "0" Pivot

Sample ID	Pivot	FMR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa \cdot m^2/g$	Burst Ind. (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57367.3	0	L	8500	71	219.7	44.3	56.8	5.00	3.67	38.59	25.59	0.79	0.210	17.9	0.250	9.8
57367.4	0	L	8500	71	219.3	39.2	56.5	4.42	3.52	40.15	25.24	0.79	0.230	17.3	0.220	8.7
57376.1	0	L	8500	71	196.7	43.3	57.9	5.13	3.78	37.41	25.19	0.81	0.260	7.1	0.230	10.7
57376.2	0	L	8500	71	194.4	41.4	56.5	4.13	4.02	34.61	22.81	0.79	0.250	6.5	0.210	15.1
57376.3	0	L	8500	71	194.2	41.0	54.3	3.90	3.70	38.05	22.68	0.80	0.210	20.3	0.210	12.8
57376.5	0	L	8500	71	195.9	42.0	57.1	4.00	4.28	38.43	25.16	0.82	0.230	3.4	0.240	5.1
57369.1	0	L	8500	204	220.1	42.9	64.3	4.41	4.34	37.37	27.14	0.89	0.260	15.3	0.270	14.1
57369.4	0	L	8500	204	204.3	44.5	66.2	5.70	5.16	37.41	25.09	0.88	0.220	17.9	0.200	18.2
57369.5	0	L	8500	204	186.1	45.8	68.8	5.23	5.34	38.93	26.48	0.86	0.260	9.7	0.230	8.4
57374.2	0	H	8500	149	215.9	44.7	63.9	4.17	4.78	39.37	24.55	0.83	0.290	8.4	0.260	14.1
57374.3	0	H	8500	149	207.6	44.7	62.8	4.79	4.92	38.96	25.47	0.86	0.280	13.1	0.300	6.7
57374.4	0	H	8500	149	221.1	44.6	62.5	4.65	5.33	39.84	26.02	0.86	0.300	7.6	0.310	6.7
57457.1	0	H	8500	204	216.1	47.7	66.8	3.50	4.81	37.87	25.52	0.84	0.210	23.4	0.250	12.2
57457.2	0	H	8500	204	220.3	44.6	65.0	5.07	4.58	39.21	25.22	0.84	0.210	14.4	0.220	23.7

Table A13-Impulse Drying On The X2 Shoe Press From 52% Solids Using The Beloit "C" Roll, Felt B,"0" Pivot

Sample ID	Pivot	F M R	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) kPa·m^2/g	Burst Ind. (FS) kPa·m^2/g	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57344.1	0	L	8500	71		54.2	60.6	4.25	4.04	37.62	24.49	0.75	0.220	16.8	0.260	14.3
57344.2	0	L	8500	71		53.9	58.3	4.68	4.08	36.17	23.76	0.83	0.220	11.5	0.250	8.7
57344.3	0	L	8500	71		54.1	60.4	4.61	4.32	36.08	22.65	0.84	0.240	9.8	0.270	4.9
57344.4	0	L	8500	71		54.0	60.6	4.70	4.45	39.92	23.32	0.84	0.260	6.2	0.230	4.3
57344.5	0	L	8500	71		54.9	60.6	4.66	4.16	39.61	22.85	0.83	0.260	4.3	0.240	11.2
57346.1	0	L	8500	204		54.5	65.8	4.20	4.38	38.71	25.59	0.91	0.260	19.8	0.300	4.7
57346.2	0	L	8500	204		54.3	65.1	4.47	4.50	38.14	24.51	0.91	0.290	6.8	0.320	5.9
57346.3	0	L	8500	204		54.7	64.6	4.49	4.17	36.17	24.52	0.91	0.290	8.0	0.310	14.4
57346.4	0	L	8500	204		54.7	65.2	3.69	2.91	35.25	24.99	0.88	0.280	5.0	0.320	7.6
57346.5	0	L	8500	204		54.7	64.9	4.29	4.22	36.16	25.09	0.91	0.300	7.3	0.320	10.0
57452.1	0	L	8500	232		55.3	64.8	4.27	4.27	38.95	22.81	0.92	0.230	9.0	0.200	23.6
57452.2	0	L	8500	232		54.5	66.8	4.08	4.08	41.47	25.61	0.92	0.260	6.4	0.260	8.3
57452.3	0	L	8500	232		53.9	65.0	4.06	4.36	38.41	24.72	0.91	0.200	42.7	0.260	5.9
57348.1	0	L	8500	260		54.6	66.8	4.08	4.20	37.87	25.10	0.92	0.310	4.5	0.310	8.3
57348.2	0	L	8500	260		54.7	67.7	4.28	4.17	38.49	26.04	0.90	0.320	3.4	0.300	6.7
57348.3	0	L	8500	260		54.6	67.7	4.42	3.73	37.86	24.63	0.89	0.280	28.8	0.320	5.7
57348.4	0	L	8500	260		55.5	67.5	3.78	4.72	38.57	25.47	0.96	0.320	5.7	0.310	3.6
57348.5	0	L	8500	260		54.0	67.9	3.42	3.99	33.26	23.77	0.83	0.090	32.2	0.210	29.3
57350.2	0	L	8500	316		54.9	73.4	4.71	4.81	33.39	22.35	0.84	0.140	21.3	0.120	32.8
57350.3	0	L	8500	316		55.6	73.7	3.91	4.16	32.59	23.11	0.86	0.160	29.6	0.160	20.1
57350.5	0	L	8500	316		54.3	71.9	4.08	4.37	37.21	23.20	0.84	0.120	29.9	0.130	31.3

Table A14-Impulse Drying On The X2 Shoe Press From 52% Solids Using The Beloit "C" Roll, Felt B,"2" Pivot

Sample ID	Pivot	F M R	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa{\cdot}m^2/g$	Burst Ind. (FS) $kPa{\cdot}m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57364.1	+2	L	6000	71	203.2	54.6	59.8	4.08	4.58	37.31	23.20	0.85	0.260	7.7	0.270	4.8
57364.2	+2	L	6000	71	192.3	54.5	60.3	5.33	3.73	37.91	25.97	0.88	0.260	7.7	0.260	3.9
57454.1	+2	L	6000	204	237.3	53.8	64.0	3.75	4.35	37.94	24.84	0.91	0.280	11.3	0.270	4.8
57454.3	+2	L	6000	204	229.3	53.1	64.8	3.35	3.93	35.05	23.75	0.91	0.250	7.7	0.250	12.8
57366.1	+2	L	8500	71	195.5	51.9	60.9	4.91	4.44	39.45	24.92	0.88	0.280	5.7	0.230	10.0
57366.2	+2	L	8500	71	164.5		59.5	4.91	3.93	38.93	24.47	0.88	0.300	8.4	0.260	9.7
57366.3	+2	L	8500	71	200.4	50.9	61.1	4.34	3.91	36.21	23.38	0.90	0.290	4.5	0.250	11.9
57360.1	+2	L	8500	204	188.9		65.4	3.65	4.35	37.33	25.46	0.93	0.270	5.1	0.270	9.0
57360.2	+2	L	8500	204	218.8		66.7	3.83	4.70	33.76	24.69	0.95	0.250	18.7	0.260	7.3
57360.3	+2	L	8500	204	247.4	53.4	65.1	3.83	4.44	38.46	24.42	0.92	0.300	4.4	0.250	13.4
57360.4	+2	L	8500	204	242.3	53.3	65.7	3.43	4.96	35.09	24.62	0.94	0.300	6.7	0.270	4.8
57360.5	+2	L	8500	204	233.2	53.5	66.0	4.06	4.24	38.93	24.98	0.95	0.300	6.1	0.270	8.8
57358.1	+2	L	8500	260	217.9			4.23	4.74	39.50	26.59	0.91	0.270	3.3	0.270	9.6
57358.2	+2	L	8500	260	236.5	52.4	67.9	4.99	5.39	38.27	26.59	0.92	0.290	5.6	0.270	7.8
57358.3	+2	L	8500	260	240.8	52.3	64.9	3.70	5.30	37.32	26.39	0.91	0.240	8.2	0.250	9.9
57358.4	+2	L	8500	260	234.7	52.5	63.0	4.27	4.77	38.13	26.77	0.91	0.280	10.1	0.270	25.8
57358.5	+2	L	8500	260	226.6	52.6	62.8	4.05	5.34	38.61	27.02	0.94	0.280	5.8	0.250	14.1

Table A15-Impulse Drying On The X2 Shoe Press From 52% Solids Using The Beloit "C" Roll, Felt R,"0" Pivot

Sample ID	Pivot	FMR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa \cdot m^2/g$	Burst Ind. (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57368.1	0	L	8500	71	193.3	61.2	63.1	3.58	3.33	34.45	22.42	0.81	0.220	15.7	0.210	9.3
57368.2	0	L	8500	71	196.7	55.3	62.5	4.11	3.68	35.05	22.61	0.79	0.190	23.0	0.200	12.1
57368.3	0	L	8500	71	191.2	52.6	58.5	4.19	3.71	36.33	22.89	0.79	0.170	24.4	0.210	12.2
57368.4	0	L	8500	71	196.7	51.7	59.3	3.97	3.83	35.76	23.64	0.78	0.180	10.9	0.210	7.6
57456.1	0	L	8500	204	198.6	51.7	66.5	5.10	5.66	38.43	24.41	0.87	0.230	14.2	0.240	13.6
57456.2	0	L	8500	204	201.3	51.4	65.7	5.52	5.17	41.22	26.72	0.90	0.280	6.8	0.280	7.8
57456.3	0	L	8500	204	208.1	51.2	65.9	4.75	5.08	38.32	26.55	0.88	0.220	11.7	0.250	6.5
57456.4	0	L	8500	204	207.0	51.5	65.8	5.09	4.66	38.15	27.15	0.87	0.230	10.9	0.260	12.2
57456.5	0	L	8500	204	195.9	51.7	66.6	4.65	4.71	40.72	23.20	0.86	0.240	8.3	0.160	43.0
57375.1	0	H	8500	149	220.6	52.4	64.0	4.30	4.01	36.53	25.65	0.87	0.290	10.8	0.300	10.7
57375.2	0	H	8500	149	230.7	51.9	63.5	3.78	3.70	38.99	25.82	0.87	0.290	6.6	0.290	6.2
57375.3	0	H	8500	149	204.7	51.4	63.8	3.74	3.42	40.16	25.92	0.88	0.300	6.3	0.320	6.2
57375.4	0	H	8500	149	211.7	51.7	64.2	5.11	5.01	39.59	26.03	0.87	0.310	7.8	0.300	7.3
57375.5	0	H	8500	149	239.8	52.5	63.3	4.32	3.62	38.53	27.30	0.87	0.280	5.4	0.270	7.7
57373.1	0	H	8500	204	196.8	60.3	69.5	4.66	4.77	40.29	27.63	0.93	0.280	6.7	0.310	5.5
57373.2	0	H	8500	204	203.7	60.0	69.4	3.04	4.51	40.62	26.13	0.88	0.270	12.1	0.290	19.7
57458.1	0	H	8500	204	198.0	52.1	67.6	4.35	5.09	38.59	26.14	0.88	0.290	6.6	0.250	7.5

Table A16 -Impulse Drying On The X2 Shoe Press From 42% Solids Using The Ceramic Coated Roll, Felt B,"0" Pivot

Sample ID	Felt MR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa·m^2/g$	Burst Ind. (FS) $kPa·m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57325.1	L	4000	68	229.8	40.3	53.6	3.50	2.87	37.05	22.42	0.71	0.190	8.8	0.200	9.1
57325.2	L	4000	68	228.8	40.4	53.6	3.28	2.79	31.29	21.88	0.70	0.150	18.5	0.160	16.7
57325.3	L	4000	68	222.9	40.2	53.6	3.25	2.85	37.11	22.25	0.70	0.200	13.2	0.170	13.9
57325.4	L	4000	68	229.3	39.7	54.1	3.74	3.28	35.13	23.12	0.70	0.160	5.6	0.190	9.2
57325.5	L	4000	68	222.9	39.6	53.8	3.77	3.07	33.12	23.83	0.69	0.140	14.4	0.200	15.4
57343.1	L	4000	149	225.5	37.9	55.4	3.56	3.74	35.27	23.40	0.73	0.170	11.7	0.190	14.0
57343.2	L	4000	149	174.7	42.0	58.3	4.24	3.45	33.08	22.36	0.76	0.160	46.2	0.180	14.8
57343.3	L	4000	149	183.9	44.7	57.4	4.26	3.68	37.03	22.44	0.79	0.160	6.8	0.170	7.6
57361.2	L	4000	204	212.9	41.9	51.5	3.71	4.10	33.26	22.92	0.66	0.100	4.2	0.130	17.3
57361.3	L	4000	204	216.0	42.5	51.3	4.72	4.21	33.01	23.10	0.64	0.100	25.0	0.130	23.2
57361.4	L	4000	204	221.7	42.0	50.8	2.88	3.55	31.17	20.01	0.62	0.080	24.4	0.080	18.1
57379.3	L	4000	260	222.0	45.4	53.4	3.42	3.33	35.82	20.53	0.70	0.120	12.7	0.120	12.2
57326.2	L	6000	68	181.8	45.8	56.3	4.59	4.44	37.04	24.13	0.80	0.240	12.1	0.270	16.9
57326.4	L	6000	68	179.4	43.1	57.5	5.05	4.31	37.54	25.74	0.79	0.220	5.4	0.270	6.3
57326.5	L	6000	68	180.4	43.5	57.4	4.46	4.01	38.47	24.60	0.81	0.250	7.6	0.240	31.8
57362.2	L	6000	204	213.8	41.8	53.2	4.23	3.94	35.41	22.64	0.70	0.140	26.4	0.160	31.4
57362.3	L	6000	204	215.3	42.1	53.1	4.84	4.27	35.46	21.91	0.69	0.140	26.8	0.130	21.9
57362.4	L	6000	204	219.7	42.6	53.8	5.08	4.87	35.86	22.08	0.77	0.150	9.4	0.130	14.1
57380.1	L	6000	260	223.6	41.2	57.2	3.05	3.47	35.16	21.36	0.72	0.120	10.7	0.100	13.7

Table A17-Impulse Drying On The X2 Shoe Press From 42% Solids Using The Ceramic Coated Roll, Felt B,"0" Pivot

Sample ID	Felt MR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa \cdot m^2/g$	Burst Ind. (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57327.1	L	8500	68	182.8	41.4	58.2	4.78	3.76	40.30	24.21	0.82	0.310	9.4	0.290	9.6
57327.2	L	8500	68	183.4	41.7	57.1	4.23	3.82	38.84	25.23	0.79	0.270	23.0	0.260	7.8
57327.3	L	8500	68	180.9	41.1	57.9	4.52	3.84	41.17	25.31	0.83	0.280	7.9	0.260	11.7
57327.4	L	8500	68	226.7	48.1	58.8	4.14	3.29	40.39	27.07	0.84	0.330	9.8	0.320	5.0
57327.5	L	8500	68	226.2	42.2	56.3	3.87	3.67	38.70	24.22	0.83	0.250	4.3	0.260	7.1
57363.1	L	8500	204	186.8	47.0	55.8	4.32	4.40	32.33	20.06	0.77	0.130	33.6	0.150	39.9
57363.2	L	8500	204	187.3	45.7	54.2	3.29	3.92	37.06	20.31	0.79	0.250	21.5	0.110	34.9
57363.3	L	8500	204	185.9	45.1	55.4	4.21	4.06	38.64	22.18	0.80	0.230	14.5	0.110	38.6
57363.4	L	8500	204	192.7	45.2	54.0	4.11	3.87	30.86	19.58	0.71	0.090	19.6	0.080	21.5
57363.5	L	8500	204	188.0	47.2	55.2	3.91	4.11	37.75	19.95	0.75	0.190	34.4	0.110	38.3
57381.1	L	8500	260	211.0	44.2	56.3	3.98	3.49	33.95	22.62	0.79	0.180	10.2	0.150	17.1
57381.2	L	8500	260	213.0	41.2	53.0	4.27	4.51	35.25	23.33	0.79	0.130	14.1	0.140	8.8
57381.3	L	8500	260	215.8	40.7	54.8	3.90	4.46	38.53	24.68	0.77	0.170	12.5	0.150	15.1
57381.4	L	8500	260	217.1	40.6	53.1	4.53	4.30	36.37	21.30	0.74	0.120	8.2	0.090	12.8
57381.5	L	8500	260	214.5	40.9	53.9	4.24	3.85	35.96	22.67	0.78	0.140	13.9	0.120	13.8
57304.3	L	8500	260	236.1	44.2	58.3	3.49	4.26	35.55	22.02	0.78	0.130	9.0	0.140	9.3

Table A18-Impulse Drying On The X2 Shoe Press From 42% Solids Using The Ceramic Coated Roll, Felt B,"0" Pivot

Sample ID	Felt MR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa·m^2/g$	Burst Ind. (FS) $kPa·m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57306.1	H	6000	260	241.3	43.9	51.9	3.17	3.53	31.34	19.34	0.66	0.100	22.8	0.090	7.1
57398.1	H	6000	316	190.2	42.2	49.5	3.89	3.40	28.19	15.36	0.62	0.070	21.1	0.070	10.8
57398.4	H	6000	316	180.1	37.6	50.6	3.15	4.91	31.90	20.62	0.70	0.080	16.7	0.110	48.2
57308.1	H	8500	260	224.0	44.3	52.8	3.09	4.06	33.39	20.40	0.72	0.110	13.2	0.090	8.8
57308.2	H	8500	260	223.7	43.8	52.7	3.00	4.09	31.88	21.68	0.71	0.090	14.4	0.110	8.6
57314.1	H	8500	260	209.9	44.9	54.0	3.50	4.47	31.87	22.23	0.76	0.100	12.1	0.100	11.5
57314.2	H	8500	260	218.2	45.5	54.2	4.00	4.06	36.20	22.67	0.75	0.100	10.8	0.100	11.0
57314.3	H	8500	260	211.8	45.2	54.0	4.14	4.62	34.90	22.24	0.73	0.090	10.8	0.090	12.2
57316.1	H	8500	316	209.2	43.7	57.0	4.06	3.88	34.20	20.59	0.81	0.110	18.8	0.120	18.6
57316.2	H	8500	316	203.7	44.5	56.7	3.20	4.33	34.39	23.14	0.79	0.120	12.1	0.110	9.2
57316.3	H	8500	316	208.7	44.1	55.3	3.95	4.21	35.68	22.13	0.78	0.110	8.0	0.100	20.8
57316.4	H	8500	316	205.5	43.7	61.6	4.31	4.09	34.93	25.70	0.83	0.170	42.5	0.230	8.8
57316.5	H	8500	316	202.8	42.3	53.6	3.25	3.95	34.39	22.76	0.77	0.100	10.8	0.120	17.9
57399.1	H	8500	316	211.7	41.1	54.8	3.73	4.10	33.85	23.69	0.77	0.100	16.8	0.130	10.5
57399.2	H	8500	316	220.9	40.6	54.3	4.17	4.99	33.47	23.17	0.72	0.100	14.0	0.100	11.0
57399.3	H	8500	316	211.0	40.6	53.1	3.76	4.14	33.70	22.90	0.74	0.110	10.1	0.100	10.0
57399.4	H	8500	316	251.0	40.9	52.8	4.15	4.03	33.79	22.38	0.75	0.090	16.0	0.090	6.5

Table A19-Impulse Drying On The X2 Shoe Press From 52% Solids Using The Ceramic Coated Roll, Felt B,"0" Pivot

Sample ID	Felt MR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa{\cdot}m^2/g$	Burst Ind. (FS) $kPa{\cdot}m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57334.1	L	4000	68	226.7	55.1	56.1	3.71	3.38	33.94	24.89	0.72	0.130	9.8	0.170	6.6
57334.2	L	4000	68	217.4	47.8	54.7	3.84	2.90	36.37	22.62	0.72	0.140	10.2	0.160	16.4
57334.3	L	4000	68	222.6	51.2	55.4	3.07	3.52	34.86	22.32	0.74	0.130	11.2	0.170	13.2
57334.4	L	4000	68	216.3	51.8	55.5	3.43	3.13	34.34	22.05	0.73	0.150	13.2	0.160	12.2
57334.5	L	4000	68	226.9	52.0	55.4	4.37	3.88	33.00	22.72	0.75	0.130	9.0	0.160	10.9
57352.1	L	4000	149	214.1	54.3	58.0	4.16	3.56	36.82	21.64	0.76	0.150	7.5	0.150	9.3
57352.3	L	4000	149	222.2	53.6	57.9	4.11	3.09	29.29	21.69	0.74	0.130	8.4	0.150	16.3
57352.5	L	4000	149	217.5	52.5	57.1	3.35	3.38	33.02	21.08	0.75	0.150	3.2	0.130	4.8
57442.1	L	4000	204	209.2	53.0	58.8	4.76	3.29	35.52	26.31	0.76	0.160	12.7	0.190	8.0
57442.3	L	4000	204	207.3	52.3	58.9	3.21	2.94	34.63	26.08	0.73	0.160	7.7	0.160	12.9
57442.4	L	4000	204	213.2	52.0	58.1	3.11	3.23	34.51	26.24	0.73	0.170	7.5	0.170	8.1
57442.5	L	4000	204	206.8	51.8	58.9	3.20	2.87	33.77	24.55	0.74	0.140	8.4	0.170	11.5
57388.1	L	4000	260	188.2	54.3	57.3	3.75	4.12	37.17	22.92	0.78	0.140	7.3	0.140	10.5
57388.2	L	4000	260	199.8	53.1	56.4	4.01	3.74	36.47	22.77	0.75	0.130	11.1	0.130	15.0
57388.3	L	4000	260	196.6	53.2	56.1	3.57	4.22	36.59	22.81	0.74	0.130	12.7	0.150	12.2
57388.4	L	4000	260	193.6	53.1	56.2	3.92	4.67	35.87	21.97	0.76	0.130	21.3	0.140	10.1
57388.5	L	4000	260	191.9	53.2	56.2	4.13	4.23	35.56	22.58	0.76	0.120	15.7	0.150	7.3

Table A20 -Impulse Drying On The X2 Shoe Press From 52% Solids Using The Ceramic Coated Roll, Felt B,"0" Pivot

Sample ID	Felt MR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa·m^2/g$	Burst Ind. (FS) $kPa·m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57335.1	L	6000	68	211.4	47.9	55.3	3.23	3.17	36.21	25.15	0.77	0.190	9.5	0.200	7.3
57335.2	L	6000	68	227.2	49.9	56.7	3.93	3.33	36.55	23.63	0.77	0.170	15.2	0.190	10.7
57335.3	L	6000	68	224.1	50.5	56.9	4.11	3.24	34.61	21.60	0.77	0.170	11.3	0.160	14.4
57335.4	L	6000	68	202.9	50.3	57.0	3.60	3.53	35.23	21.28	0.77	0.210	13.0	0.160	18.4
57335.5	L	6000	68	203.2	51.3	57.2	3.79	4.12	33.18	21.45	0.79	0.180	5.7	0.160	9.8
57353.1	L	6000	166	208.1	53.7	61.2	3.83	3.93	32.23	20.43	0.80	0.150	14.2	0.150	15.9
57353.2	L	6000	166	203.9	53.4	59.5	4.04	3.90	33.60	22.66	0.76	0.140	17.1	0.170	11.2
57353.3	L	6000	166	205.0	53.0	59.8	3.41	3.67	36.45	22.97	0.81	0.200	10.0	0.180	14.8
57353.4	L	6000	166	217.2	53.5	59.8	4.01	3.39	34.89	23.46	0.81	0.190	6.3	0.210	10.9
57353.5	L	6000	166	202.6	53.3	59.2	4.08	3.16	36.44	22.21	0.82	0.180	5.1	0.190	9.4
57370.1	L	6000	204	217.6	59.0	61.2	3.91	3.04	32.77	22.32	0.79	0.190	15.3	0.220	5.1
57370.2	L	6000	204	194.5	54.6	62.2	4.73	4.22	39.75	24.71	0.81	0.190	16.5	0.210	8.9
57370.3	L	6000	204	189.1	53.9	61.3	3.98	3.32	40.24	24.20	0.80	0.200	7.7	0.210	7.6
57370.4	L	6000	204	196.8	54.0	61.2	3.40	3.89	37.51	24.00	0.79	0.190	5.4	0.180	15.2
57370.5	L	6000	204	191.5	53.5	61.4	3.65	4.01	37.47	23.72	0.82	0.200	6.4	0.210	5.8
57371.1	L	6000	204	210.9	53.9	61.7	4.11	3.59	38.31	23.96	0.80	0.200	12.8	0.240	10.7
57371.2	L	6000	204	210.0		61.1	3.78	3.95	40.01	23.45	0.80	0.180	13.6	0.190	13.1
57371.3	L	6000	204	201.6	53.0	62.1	4.41	3.30	35.10	23.93	0.78	0.170	9.0	0.190	15.5
57371.4	L	6000	204	203.4	52.9	63.1	4.14	4.10	36.11	23.43	0.76	0.160	9.2	0.200	13.3
57389.5	L	6000	260	199.8	53.5	60.4	4.09	3.99	35.32	23.01	0.81	0.180	8.5	0.170	8.7

Table A21-Impulse Drying On The X2 Shoe Press From 52% Solids Using The Ceramic Coated Roll, Felt B,"0" Pivot

Sample ID	Felt MR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa \cdot m^2/g$	Burst Ind. (FS) $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57336.1	L	8500	68	215.2	52.0	58.2	4.09	3.39	37.67	23.80	0.82	0.240	8.5	0.230	12.7
57336.2	L	8500	68	222.3	51.5	58.7	4.44	3.63	38.35	24.80	0.85	0.250	9.2	0.240	12.9
57336.3	L	8500	68	218.0	51.7	58.9	3.45	3.77	37.90	24.64	0.81	0.250	6.8	0.230	11.2
57336.4	L	8500	68	215.9	52.8	57.1	3.74	4.00	36.41	24.18	0.81	0.240	5.0	0.240	16.9
57336.5	L	8500	68	228.4	53.7	58.1	4.70	3.79	38.81	25.74	0.85	0.260	7.3	0.270	9.2
57354.1	L	8500	179	240.1		60.7	3.36	3.74	38.59	22.79	0.85	0.240	8.6	0.230	4.4
57354.3	L	8500	179			62.8	3.72	3.56	35.20	23.79	0.88	0.210	10.3	0.280	13.4
57354.4	L	8500	179	205.9	54.3	61.1	3.28	4.40	39.74	25.75	0.85	0.250	5.6	0.260	5.5
57372.1	L	8500	204	209.9	54.5	60.5	3.74	3.78	39.29	25.87	0.81	0.180	15.9	0.250	12.6
57372.2	L	8500	204	205.0	53.7	61.3	4.32	4.59	39.94	25.76	0.83	0.260	17.8	0.220	19.5
57372.3	L	8500	204	205.3	53.7	59.7	3.41	4.43	39.46	27.22	0.83	0.220	24.2	0.310	12.0
57372.4	L	8500	204	211.3	54.1	61.1	3.97	4.01	39.13	26.60	0.85	0.250	6.5	0.270	10.1
57372.5	L	8500	204	209.3	54.1	61.4	4.15	3.67	40.64	24.74	0.82	0.230	17.8	0.260	14.8
57390.1	L	8500	260	200.1	53.5	62.0	3.57	4.27	37.32	26.84	0.89	0.220	9.2	0.250	12.2
57390.3	L	8500	260	184.9	52.7	59.5	4.54	4.84	39.39	24.81	0.84	0.160	13.8	0.180	8.9
57390.4	L	8500	260	209.9	53.3	61.0	4.13	3.98	39.79	25.52	0.88	0.240	9.4	0.270	9.0

Table A22 -Impulse Drying On The X2 Shoe Press From 52% Solids Using The Ceramic Coated Roll, Felt B,"0" Pivot

Sample ID	Felt MR	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	Burst Ind. (WS) $kPa{\cdot}m^2/g$	Burst Ind. (FS) $kPa{\cdot}m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Dens g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57307.3	H	6000	260	183.6	51.5	56.6	4.10	3.68	37.03	23.63	0.75	0.140	21.7	0.190	24.5
57407.1	H	6000	316	233.3	52.5	57.2	3.67	4.17	37.20	25.40	0.79	0.180	9.6	0.200	9.9
57308.3	H	8500	260		56.2		3.92	4.54	33.09	22.57	0.73	0.110	10.7	0.120	11.9
57309.1	H	8500	260	185.3	51.8	60.0	4.40	4.21	39.69	24.90	0.82	0.200	16.2	0.210	12.7
57309.2	H	8500	260	182.7	52.5	59.6	4.00	3.96	37.31	25.49	0.84	0.180	13.7	0.220	7.7
57315.1	H	8500	260	223.2	52.9	61.3	4.30	3.92	36.39	23.48	0.80	0.150	16.9	0.150	12.7
57315.2	H	8500	260	215.9	52.5	60.7	3.19	4.68	37.04	21.97	0.84	0.200	13.1	0.230	11.7
57443.1	H	8500	260	190.3	53.3	62.0	4.30	3.94	37.78	23.18	0.78	0.140	22.0	0.170	8.2
57443.2	H	8500	260	191.8	52.7	59.6	4.06	4.48	38.73	25.31	0.82	0.170	15.4	0.210	18.0
57443.3	H	8500	260	190.3	52.3	61.9	4.04	3.78	38.38	22.86	0.82	0.180	9.7	0.170	12.1
57443.4	H	8500	260	234.3	52.3	58.7	4.23	4.23	38.79	25.48	0.80	0.200	12.6	0.180	14.7
57443.5	H	8500	260	230.8	52.2	61.0	4.39	4.17	39.15	23.92	0.84	0.230	17.9	0.190	8.8
57317.1	H	8500	316	209.9	51.8	61.7	3.68	3.77	36.65	28.28	0.85	0.280	6.1	0.310	10.8
57317.2	H	8500	316	202.8	51.9	61.7	3.78	3.85	37.60	25.34	0.83	0.150	17.9	0.220	9.9
57317.3	H	8500	316	203.0	52.2	62.8	3.77	4.98	38.76	25.98	0.87	0.190	11.3	0.200	8.9
57317.4	H	8500	316	205.3	51.5	60.4	4.23	3.73	36.93	28.52	0.87	0.260	8.5	0.290	12.2
57317.5	H	8500	316	212.7	52.1	61.2	3.70	4.00	37.69	26.50	0.87	0.240	7.1	0.260	8.4
57318.1	H	8500	316	206.4	51.4	60.2	4.49	4.33	36.58	27.31	0.86	0.220	21.1	0.300	2.6
57318.2	H	8500	316	212.6	51.6	60.6	3.94	3.88	35.09	26.13	0.90	0.250	9.4	0.300	15.2
57318.3	H	8500	316	203.3	51.8	61.5	3.65	4.13	39.01	23.63	0.83	0.190	12.0	0.150	15.2
57318.4	H	8500	316	203.7	52.1	61.3	3.68	4.08	36.26	24.59	0.79	0.150	11.0	0.190	18.4
57318.5	H	8500	316	198.6	52.2	61.0	4.94	4.30	38.04	24.28	0.83	0.200	7.6	0.190	9.4
57408.1	H	8500	316	197.5	53.0	59.7	3.51	4.95	40.52	23.94	0.82	0.180	7.3	0.170	13.3
57408.2	H	8500	316	195.4	52.7	59.6	3.70	4.77	37.66	24.64	0.79	0.100	28.6	0.170	16.8
57408.5	H	8500	316	208.4	52.8	60.0	3.44	2.16	38.47	24.52	0.78	0.140	15.7	0.180	19.7

Table A23 -Impulse Drying On The IPST Roll Press From Using The Ceramic Coated Roll, Standard IPST Felt

Sample ID	Press Load pli	Roll Temp °C	B. Wt. g/m^2	Solids In %	Solids Out %	(WS) Burst Index, kPa·m^2/g	MDSTFI Index N·m/g	CDSTFI Index N·m/g	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
WK9ZF	315	105	227.7	39.9	45.5	2.160	20.12	13.32	0.033	11.9	0.038	14.8
WK9O	315	150	212.7	38.5	50.7	3.101	25.53	15.68	0.050	14.8	0.051	11.7
WK9A	315	200	216.1	40.9	55.0	3.030	27.34	16.91	0.059	12.6	0.057	13.8
WK9M	315	250	218.0	39.4	57.0	3.363	28.32	17.74	0.078	19.3	0.090	17.5
WK9K	315	250	205.7	39.1	58.0	3.621	28.04	17.95				
WK9D	315	250	245.8	40.9	57.2	3.478	31.63	19.72				
WK9C	315	250	182.0	45.5	54.5	3.296	30.02	19.36				
WK9E	315	300	239.8	41.6	58.2	3.335	31.89	19.64	0.095	14.8	0.094	13.9
WK9G	315	350	207.3	39.2	58.7	3.903	33.28	21.34				
WK9J	315	400	220.3	39.6	61.8	3.338	28.20	19.18				
WK9ZE	315	105	240.2	48.6	50.9	3.273	26.54	16.91	0.060	18.1	0.055	12.7
WK9N3	315	150	240.4	48.7	52.4	2.964	27.24	17.15	0.064	9.4	0.062	8.9
WK9B	315	200	206.4	49.6	56.6	3.007	28.81	16.62	0.065	12.4	0.070	13.6
WK9L	315	250	215.4	49.3	58.9	3.319	29.45	18.93	0.082	12.1	0.086	15.1
WK9F	315	300	232.1	48.7	58.3	3.040	32.55	21.51	0.114	12.3	0.116	7.2
WK9H	315	350	217.0	49.3	61.1	4.247	34.28	24.85				
WK9I	315	400	213.1	51.0	62.7	4.336	35.52	24.17				
WK9ZC	472	105	218.3	42.3	54.0	3.168	30.70	18.65	0.086	13.1	0.084	15.2
WK9Q	472	150	193.4	39.8	53.4	3.255	29.12	18.09	0.084	14.7	0.073	17.4
WK9R	472	200	208.9	40.5	56.0	3.598	32.98	20.76	0.140	11.7	0.129	13.4
WK9T	472	250	211.8	39.9	59.3	3.645	34.18	21.78	0.156	14.3	0.167	11.2
WK9X	472	300	225.7	40.0	60.4	3.819	32.92	20.41	0.149	18.3	0.145	16.4
WK9Y	472	350	219.6	40.2	62.0	3.695	28.60	17.30	0.080	35.0	0.440	39.6
WK9ZB	472	400	230.9	39.4	65.0	3.214	21.88	13.68				
WK9ZD	472	105	214.2	48.6	52.2	2.661	30.66	18.34	0.078	14.9	0.070	12.4
WK9P	472	150	252.5	49.6	54.0	3.141	26.43	16.18	0.060	16.4	0.054	12.9
WK9S	472	200	228.2	51.0	58.0	3.334	30.40	19.33	0.103	12.9	0.096	11.1
WK9U	472	250	223.2	49.0	59.4	3.295	34.30	20.78	0.132	14.2	0.130	13.2
WK9W	472	300	225.1	50.0	61.7	3.654	33.25	20.82	0.132	10.1	0.129	10.9
WK9Z	472	350	240.4	50.1	62.4	3.355	30.92	19.88	0.140	12.2	0.131	21.9
WK9ZA	472	400	239.7	50.0	65.4	2.598	22.72	14.22				

Table A24 -Impulse Drying On The Beloit HRP Roll Press From Using The Ceramic Coated Roll, Felt B.

Sample ID	Press Load pli	Roll Temp °C	Solids In %	Solids Out %	(WS) Burst Index, kPa·m^2/g	(FS) Burst Index, kPa·m^2/g	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57471.1	530	71	41.8	52.0	3.67	3.51	30.14	18.71	0.68	0.130	21.3	0.110	14.0
57471.2	530	71	41.8	52.6	3.69	3.63	30.77	18.98	0.70	0.130	8.2	0.130	10.1
57471.3	530	71	40.5	52.1	3.12	3.69	30.40	20.33	0.69	0.130	14.6	0.140	9.6
57471.4	530	71	43.3	55.5	3.67	2.94	31.28	20.08	0.69	0.140	9.6	0.120	9.4
57471.5	530	71	41.6	52.9	3.47	3.53	29.94	20.34	0.67	0.120	15.1	0.130	12.8
57467.1	530	160	44.4	53.2	3.93	3.06	30.84	21.38	0.74	0.130	14.8	0.140	8.9
57467.2	530	160	44.6	53.6	3.58	3.87	28.82	19.05	0.70	0.090	19.4	0.090	11.1
57467.3	530	160	42.4	53.9	3.26	3.37	30.87	17.88	0.71	0.100	9.6	0.090	9.3
57467.4	530	160	42.3	50.6	2.80	3.39	29.98	18.79	0.68	0.080	13.9	0.090	15.1
57467.5	530	160	42.4	54.2	3.14	3.70	31.43	19.22	0.72	0.090	9.7	0.110	14.9
57468.1	530	210	42.3	58.9	3.03	4.24	32.29	20.56	0.79	0.100	12.9	0.100	11.7
57468.2	530	210	42.7	59.4	3.93	4.61	32.43	21.23	0.81	0.120	10.7	0.130	14.6
57468.3	530	210	43.0	57.4	3.40	4.55	31.55	20.40	0.79	0.110	6.4	0.110	9.9
57468.4	530	210	43.5	59.0	3.51	4.09	33.25	21.75	0.82	0.130	14.5	0.130	16.4
57468.6	530	210	43.7	58.4	3.41	4.38	31.79	20.68	0.77	0.130	24.2	0.110	9.1
57469.1	530	266	43.1	62.9	4.39	4.79	33.78	23.62	0.83	0.220	13.0	0.200	19.2
57469.2	530	266	42.4	63.1	4.88	5.09	36.73	23.20	0.85	0.240	8.0	0.200	23.5
57469.3	530	266	42.6	62.9	4.59	4.74	36.80	23.03	0.84	0.230	7.0	0.180	24.2
57469.4	530	266	43.2	63.2	3.60	5.10	35.95	24.17	0.87	0.220	6.5	0.200	14.1
57469.5	530	266	42.4	60.9	4.79	4.79	37.06	23.78	0.85	0.220	9.3	0.180	27.8
57470.1	530	316	43.9	65.9	5.02	4.87	39.00	25.62	0.85	0.240	8.3	0.210	15.5
57470.2	530	316	44.8	65.3	4.35	3.94	37.48	26.69	0.85	0.230	9.3	0.230	11.9
57470.3	530	316	45.9	66.5	4.08	4.64	38.17	26.35	0.86	0.230	11.6	0.230	9.0
57470.4	530	316	47.4	66.9	3.82	4.74	37.49	25.82	0.85	0.220	15.7	0.220	12.1
57470.5	530	316		66.5	5.14	4.60	40.48	24.28	0.86	0.280	7.6	0.200	26.7

Table A25 -Double Felted Pressing On The Beloit HRP Roll Press From Using The Ceramic Coated Roll, Felt B

Sample ID	Press Load pli	Roll Temp °C	Solids In %	Solids Out %	(WS) Burst Index, $kPa \cdot m^2/g$	(FS) Burst Index, $kPa \cdot m^2/g$	MD STFI Index N·m/g	CD STFI Index N·m/g	IPC Density g/cm^3	MD SEM MN·m/kg	MD CV SEM %	CD SEM MN·m/kg	CD CV SEM %
57466.1	530	71	45.4	50.9	2.12	2.31	27.03	15.77	0.63	0.080	12.0	0.070	10.4
57466.2	530	71	39.3	49.3	3.08	3.23	29.45	19.70	0.68	0.110	15.9	0.110	10.4
57466.3	530	71	45.6	52.1	3.17	2.36	29.97	16.41	0.64	0.100	22.6	0.080	20.7
57466.4	530	71	38.6	49.1	3.69	3.07	31.18	19.00	0.64	0.120	12.7	0.100	12.5
57466.5	530	71	38.6	50.1	4.40	2.73	31.87	20.54	0.70	0.130	18.1	0.130	14.2

END

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