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Plybonding and the Belbond Multi-Ply Former

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PLYBONDING AND THE BELBOND MULTI-PLY FORMER

by

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ABSTRACT

This study was used to evaluate the improved plybond strength of the paperboard produced by the BelBord Multi-ply former. Samples of the headbox and plies after the couch were tested for Canadian Standard Freeness and related to fines content. An increase in CSF after forming shows a fine loss and loss of fiber specific surface area. The plybond increase is attributed to consistency of stock during joining of the plies, the twin wire function, and dewatering in both directions of the web. Further fiber balance studies and moisture content analysis upon joining of the plies would be recommended.

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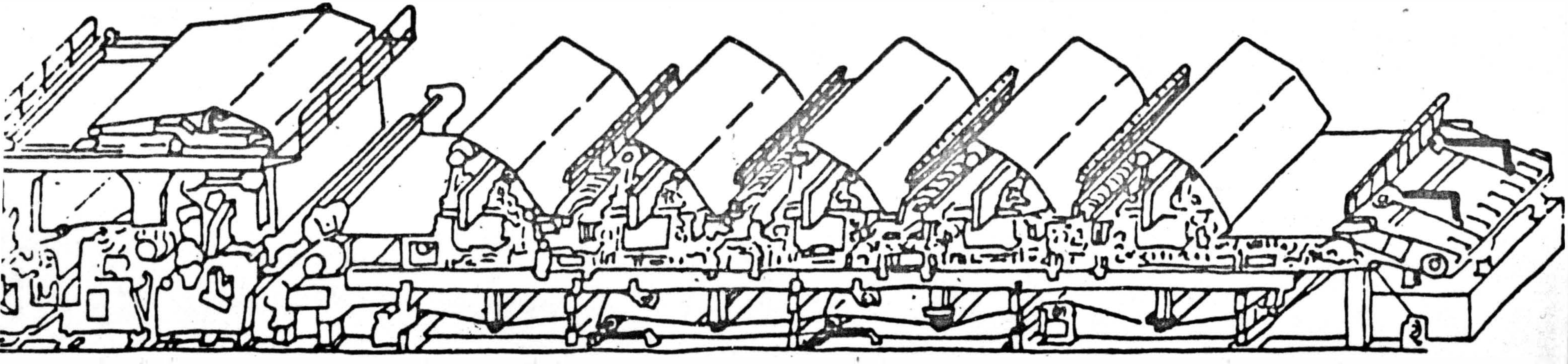
INTRODUCTION

Plybonding strength of paperboard is the force or energy required to separate the layers of a multi-ply sheet. The adhesion of the plies is dependant on many factors including moisture content at the time of joining, water removal, and pressing of the newly formed plies. The nature of the forces involved in plybonding are very like the same as those within the individual plies.

The new BelBond Multi-ply former uses a fourdrinier wire with five BelBond units for additional headboxes and dewatering, up to six plies. As this machine was starting-up in April of 1979, a good plybond was expected along with higher speeds and production.

This study will attempt to relate headbox consistency and freeness to the sheet after forming to find reason for improved plybond.



FOURDRINER, BEL-BOND
&
PRESS SECTION

ST REGIS PAPER COMPANY
RECYCLED FIBER DIVISION
Battle Creek, Michigan 49016

THEORETICAL BACKGROUND

The BelBond is a newly installed paperboard machine similar to the Inverform. It is a multi-ply forming device with a fourdrinier wire and multiple headboxes. The BelBond units act as dewatering devices. This allows drainage in two directions as the sheet is sandwiched between the top and bottom wires. (1)

The migration of fines plays a major role in plybonding. As the freeness of stock decreases, this is related to a higher degree of refining and more fiber surface area. More surface area promotes better bonding. As the fines are lost in formation and during pressing, bonding decreases.

This study investigates the stock used on the BelBond after refining and in successive stages through formation. It is hoped to relate the surface area by Canadian Standard Freeness to bonding in the plies. Other equipment available for analysis of the plybond is the BRDA plybond tester and plybond Mullen.

The furnish used is basically the same for the runs to be tested. All the stock is recycled fibers for the production of folding cartons. The plybond is important during the printing process in the carton plant. The sheet must hang together during offset and gravure printing. At the range of calipers run on the machine, the higher the caliper, the more critical is the plybond.

The BelBond was a rebuild project in 1979 for St Regis at the Battle Creek recycled fiber division. The goals of the rebuild were to achieve uniform stock delivery and well dispersed fibers for uniform formation. Also applying a low consistency layer of stock onto the wet ply to provide maximum water and fines migration for a good bond between plies. The old Angel Mill consisted of Stevens type pressure cylindars on 1, 7, and 8, the filler being applied by counterflow vats. The wet end and press section were removed and replaced by the C-frame cantilever fourdrinier and five BelBond units and a Tri-nip press. The two channel Converflo headbox is the primary with four more headboxes. The first BelBond is an upward dewatering unit. Numbers 2 thru 5 are preceded by the secondary Converflos. (3)

The objective of the rebuild is to provide a high quality printing surface, uniform formation, superior plybond, a level weight profile, higher yield, improve stiffness ratio, and gain consistency from run to run. The BelBond fourdrinier offers a wider range of calipers on standard boxboard grades. Multi-layered paperboard shows an improvement in fiber economy and sheet properties. The BelBond occupies less space than the Inverform and has fewer wire rolls and a curved former zone, similar to the Bel Baie. (4)

The Strato-flo Converflo primary headbox was especially developed to operate in conjunction with successive BelBond formers. The two channel headbox has a rectangular inlet header that maintains the even stock pressure distribution needed for cross-machine uniformity and fiber dispersion.

The tube bank has offset rows of straight tubes providing stable flow to the Converflo element. The converflo section has flexible trailing sheets which converge to help stratify the flow and dampen disturbances to only the microturbulance required for superior sheet formation.

Within the two channel Converflo headbox, two dissimilar stock flows pass through separate channels which converge at the slice to supply a stratified jet of two plies on the fourdrinier. With the two stock systems, various furnish combinations can be made.

The bottom ply drains quickly at the wet end of the table, forming a filter mat through which the top channel stock is drained. Because there are no large forces to mix the two plies, good ply definition is maintained. At the same time, top ply drainage through the bottom ply gives good fiber interlocking at the interface, which results in excellent plybond. (5)

The BelBond former is a compact four roll unit comprised of a lead-in roll, drive roll, stretch roll and guide roll, and the curved shoe scribing a 200 inch radius. Curvature of the inverted suction box assures that the two wires which sandwich the stock are held together without any possibility of wire flapping. Wire tension and curved shoes large radii generate an internal pressure between the wires, but without the relative speed differences which otherwise result in scuffing. This pressure assists dewatering, but is gentle so not disrupting the formation flowing from the thin channel headbox.

During operation, stock is discharged from the headbox to the base ply on the fourdrinier wire and into the converging nip between the bottom wire and the lead-in roll of the BelBond unit. The two wires pass over a curved foil mounted inside the bottom wire, just ahead of the lead-in wire. Pressure generated by the foil curvature and wire tension forces water through the top wire and into an autoslice.

The formed sheet between the two curved wires passes under the remaining two suction compartments with final drainage achieved in an upward direction. In the final pass, a special transfer device assures that the sheet follows the bottom wire on the fourdrinier as the two wires separate. The forming unit is designed for fabrics, and has interchangeable rolls. All rolls are doctored and showered. Vacuum and water outlets are located on the back side of the machine. (6)

The key element of the BelBond is the curved inverted vacuum box (CIVB), wrapped by the Bel wire and fourdrinier with the sandwiched sheet. The controlled vacuum levels and wire tension act together to achieve water drainage in two directions. The wet bonding of plies is similar to the Inverform and Bel Baie.

The consistency of the stock is run between 0.5 to 1.0% to gain intimate contact and migration fo fibers in the wet sheet. The lead-in vacuum box has one compartment and is located between the lead-in roll and inverted vacuum box as part of the fourdrinier table make-up. It is fitted with a polyethelene slotted cover. This is the surface where the BelBond and fourdrinier sandwich join.

The CIVB has three vacuum compartments, the autoslice and two separate suction areas, all separately controlled. They are fitted with high density polyethelene covers.

The autoslice removes the free surface water from inside the top wire following the lead-in roll. This removed water is "rich white water". Adjustments can be made by visual judgements. Too much vacuum can create cover wear and reduce cover life, waste drive horsepower. The white water does aid by acting as a lubricant.

The autoslice blade does not touch the wire but is just above it. Efficiency of the autoslice increases with speed because of increased momentum. The autoslice is not intended as part of sheet formation. Dewatering in the first suction box passes the water thru the top wire into slots in the box cover, going up channels and spilling into water removal troughs. Final drainage is upward. A special transfer device ensures the sheet follows the bottom wire as the two wires separate. (7)

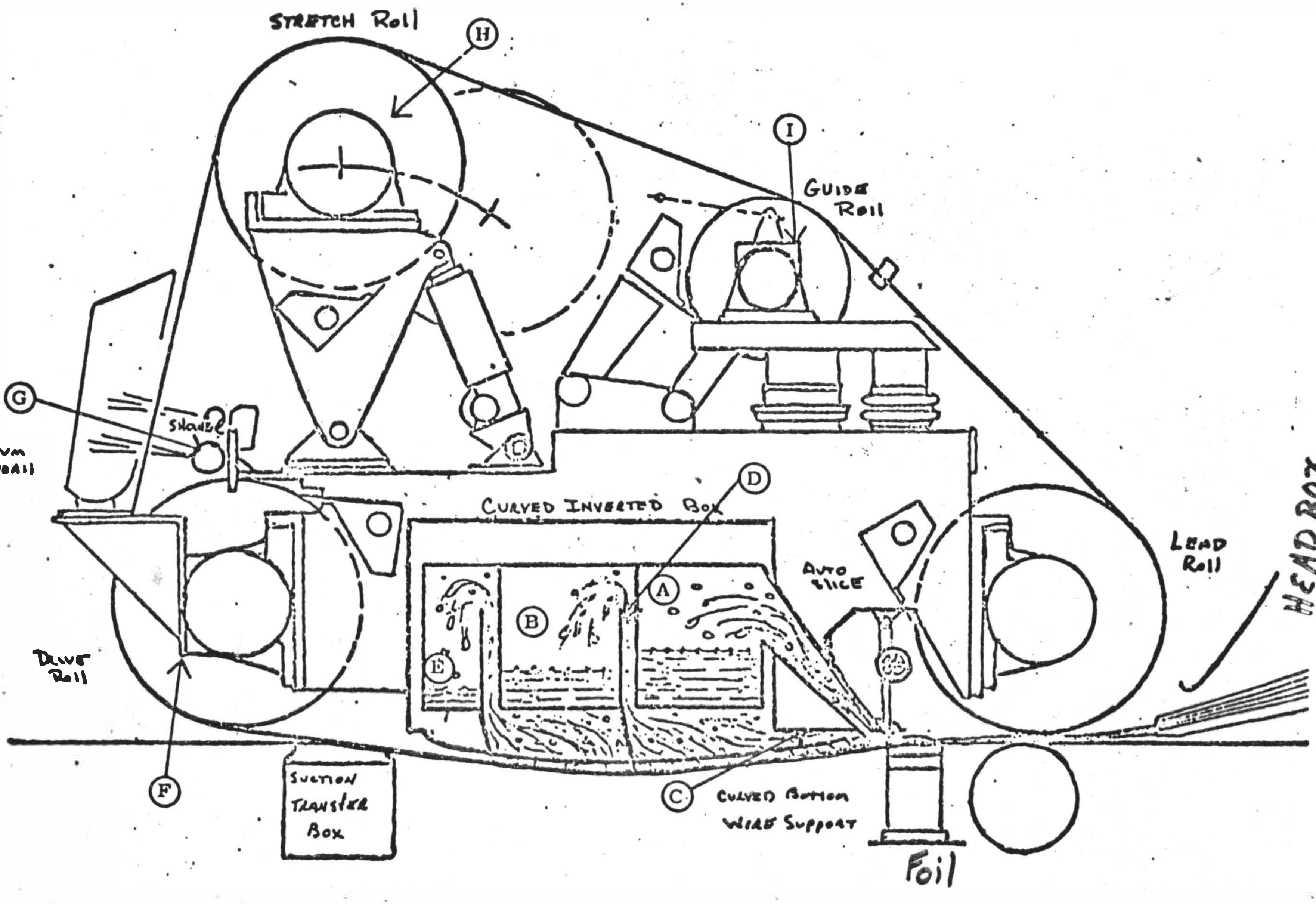

STRETCH Roll
H
I
GUIDE Roll
G
SNOZZLE
Vacuum Saveall
C
D
CURVED INVERTED Box
A
B
E
AUTO SLICE
LEAD Roll
HEAD BOX
DRIVE Roll
F
SUCTION TRANSFER Box
C
CURVED BOTTOM WIRE SUPPORT
Foil

Figure 29.

The Beloit Tri-nip press combines maximum water removal with efficient use of latest press technology to reduce energy cost per ton while retaining low stiffness ratios. The press is double felted. The sheet is transferred from the fourdrinier wire to the bottom felt and carried to the first nip composed of a top Venta-nip roll and bottom suction roll. The top felt leaves the sheet immediately following the first nip to prevent rewetting.

The sheet and bottom felt travel over the suction roll to the second nip. This third roll will have a hard cover to impart a smooth surface to the top of the sheet. The bottom felt leaves the sheet following the third nip formed by a felted press and Venta-nip Controlled Crown roll. This press has an arrangement providing three successive nips before an open draw.

A new separately felted press will follow the Tri-nip. This press has a higher nip pressure. The sheet entering the dryers will be approximately 42-48% bone dry depending on furnish, grade, weight and speed.

Plybond also plays a roll in stiffness. If the plies are well bonded to each other, they resist relative movement when the sheet is subjected to a bending force.

A study using bleached softwood kraft refined to a CSF of 400, showed a gradual increase of plybond strength as the joining moisture of the sheet was increased between 9.3 and 85%. Between 85 and 90%, small increases in moisture content yielded very large increases in plybond strength. Above 90%, fluctuations were noted beyond the control of the study. (10) Typical moisture of joining plies on a cylindar machine is 92%.

The first two plies are contacting the fourdrinier wire of the BelBond within a microsecond of each other. The moisture is very high, nearly the headbox percentage at the time of joining. As the third ply is formed, the first two plies have been dewatered in two directions. The third ply is at the headbox consistency (approximately 1.0%) as it forms on the mat joining the plies. The consistency of the mat has not been determined. The moistures would be similar to these in the following plies.

Conclusions from the literature search as to the effects of plybonding are:

1. For a given basis weight and fiber type, the more plies in the sheet the stronger the sheet becomes to an optimum number of plies for a given system.
2. The total strength of a multi-ply sheet was greater than the combined strength of the plies.
3. The stiffness of a multi-ply sheet increased in proportion to the interply bond strength.
4. The plybond strength increases with a higher degree of refining evaluated by pulp freeness.
5. As the machine calendering is increased to a given multi-ply sheet, the ply decreases in bonding strength.
6. Moisture content was found to be a critical factor in plybonding. It has been reported that the moisture content of the plies at joining should be between 70 and 90%.
7. The interweb strength approaches the intraweb strength as a limit.
8. The mechanism for bonding between the plies is the same as the mechansim for bonding within the plies.

EXPERIMENTAL

Plybond strength increases with fiber retention, providing the initial refining is substantial. (8) The strength of the stock can be measured by z-direction tensile. It is also affected by percentage of pigment such as clay fillers. The formation of the sheet changes from the initial stock supply until the final sheet is produced. The fines lost from forming and pressing can equal 5% of the total fibers. The fines are important to the plybond. It has been found by fractionization of stock samples that the fines provide more surface area for bonding the plies together.

By taking stock samples at the headboxes, and a web sample after the couch, the CSF at each point can be measured and correlated to surface area showing loss of fibers. (9) The web samples will be separated into the six plies and soaked to disintegrate the sheet. There should not be any action that will change the properties of the fibers significantly. The lower the CSF, the higher the expected z-direction tensile and plybond.

By plotting the CSF against tensile, an indirect relationship will be found. The fiber characteristics correlated by means of CSF to web strength after forming will be the method of analysis.

All the samples will be obtained on location of the BelBond Former and CSF can be tested in the mill. The tests will be conducted on varying calipers of paperboard ranging from .0175" to .024" when the furnish is of the same type and other factors such as speed and suction levels will be recorded and taken into account. The BRDA plybond tester and Mullen plybond will be run on conditioned samples in Battle Creek at St Regis constant temperature and humidity room.

RESULTS AND DISCUSSION

Canadian Standard Freeness was used to study the stock in the headboxes and the web after the couch. The headbox samples run in consistency around 1.0%. The CSF after correction for pad weight and run at a constant temperature of 20 C ranged from 180 to 270 on all the calipers. There was no specific trend in any one BelBond unit or change with calipers.

After the couch, the separate plies were tested for CSF and found to range from 440 to 570. There was a decrease in CSF from .0175 to .024" board. This is a result of a thicker fiber mat forming and allowing less drainage and loss of fines.

The table on the following page shows the averages of the trials for the four calipers of paperboard tested. The tables of trial data are contained in the appendix. The sample marked L6 is a sample of equal quantities of the six headboxes mixed then a freeness run. This was done to simulate the freeness of the total sheet which is coded W6 for the web sample, all six plies after the couch unseparated checked for freeness. W6 was found to be lower than any of the ply samples. This could be due to the separation of the plies for the freeness test where the W6 is not separated.

Z-direction tensile tests were not run due to insufficient supply of stock to make handsheets. The separation of plies took more time than expected to acquire enough sample for the freeness.

The overall increase in CSF from 200 in the headbox to 500 after the couch shows a definite loss of fines in the stock during formation. The suction or dewatering in both directions contributes to the loss but the sandwich effect of the twin wire and hydration of the fibers entangles the layers and fibers to form a less distinguishable ply. The individual plies become

TABLE I

From Headboxes	.0175"	.020"	.022"	.024"
Backliner A	248	232	214	229
Filler B	192	223	236	230
Filler C	182	251	210	217
Filler D	254	204	204	218
Underliner E	187	213	215	225
Topliner F	237	230	236	238
L6	267	258	254	249

After Couch				
A	574	554	548	478
B	555	545	543	502
C	547	539	531	498
D	520	520	514	479
E	514	502	508	469
F	489	486	484	448
W6	475	452	459	442

less defined.

By a BRDA study, an indirect relationship of CSF to percentage fines is reinforcing the loss of fines. In the 200 CSF range, it is relative to 30% and higher content of fines. When the CSF increases to 500, 10% fines are more common. (9) This also relates to specific surface in the same manner.

The stock being applied at 1.0% consistency at speeds of 600 feet per minute is an important factor of the plybond. As noted in the study by Breen (10), moisture of the sheet when plies are joined is critical. As the web is moving fast and successive layers applied within a short distance and period of time, the moisture is high and aids in plybonding as it does the intraply bond.

The BRDA values for the BelBond were higher at any caliper than the other two machines used in comparison. Plybond Mullen or the pop test for the BELBond averages 200 kg/cm^2 compared to 140 for the other machines. This increase is quite noticable when testing and at this point no printing problems have been encountered with the different tack inks. These BRDA plybond tests were not run on the actual board that was checked for freeness. It was not possible to obtain samples of the board as it is winding on the reel and the freeness testing was being conducted at that time. These samples were from the Quality Control sheet and conditioned before running the plybond tests. The Kobayashi and Stevens former are the two machines in the downtown St Regis Mill.

The sheet after the couch has a lower consistency of water then what is found on other types of formers. It runs in the 75 to 80% range while fourdriniers are generally averaging 88%. This is an advantage to the presses and saves energy in the dryer sections.

The suction applied when forming the sheet remains quite constant. This is controlled by the machine tender and is generally unchanged until a high pull of amperage is noted on a BelBond unit. The vacuum is then lowered to lessen the drag and maintain speed. A table of the suction levels is contained in the Appendix. These are samples taken during a 2 hour interval on one day of testing. These are representative of all the other readings.

BRDA PLYBOND (microamps)

	BelFond	Kobayashi	Stevens Former
	260	200	180
	350	200	140
.0175"	330	150	155
		180	170
Ave.	313	183	161
	225	250	215
	350	250	170
.020"	360	130	190
		170	160
Ave.	312	200	184
	330	220	205
	280	210	160
.022"	290	210	
	300	213	
Ave.	300	213	183
	320	270	140
	240	260	140
.024"	245	270	175
		260	
Ave.	268	265	153

CONCLUSIONS AND RECOMMENDATIONS

The plybond of the sheet is not necessarily increasing due to fiber retention. A fiber loss is noted due to increase in CSF from the headbox to the web after the couch. This loss may not be as high as other formers and this area would be worth studying further. On this machine, it is not possible to sample all the white water as it is suctioned off. There are many suction compartments on each BelBond unit and the table. A fiber balance of the machine would be suggested.

The increased plybond is aided by the twin wire sandwich and dewatering in both directions. The application of stock from the headboxes at 1.0% consistency is another factor adding to improved plybond. Another study to pursue would be the moisture content of the plies at the time of joining. This is definitly an effect of the interply strength.

APPENDIX

VACUUM INCHES OF H_2O

Autoslice	Compartment #1	Compartment #2	Transfer Box
#1 BelBond			
13	30	20	65
13	30	20	65
#2 BelBond			
19	55	65	75
19	35	60	75
#3 BelBond			
18	75	10	85
18	75	15	85
#4 BelBond			
19	25	70	70
19	25	25	70
#5 BelBond			
10	75	45	75
10	75	45	75

Foil Boxes	#1	#2	#3
	3.5	4	5
	3.5	4	5

VACUUM INCHES OF Hg

BelBond Header			Transfer Box Header		Flat Box		
#1	9.2	9.2	5.4	5.4		6.2	9.5
#2	8.6	8.8	5.4	5.4		5.8	5.8
#3	9.0	9.0	5.8	6.0	header	9.4	9.5
#4	8.8	8.8	5.2	5.4			
#5	8.8	8.8	5.5	5.5			

Suction Couch

23 23

.0175" CSF DATA

	Trial #1	Trial #2	Trial #3	Average
A	241	254	248	248
B	180	195	200	192
C	177	230	186	182
D	248	255	258	254
E	179	189	193	187
F	230	235	245	237
L6	257	264	280	267

A	564	580	579	574
B	553	548	565	555
C	544	550	548	547
D	519	525	516	520
E	513	520	510	514
F	489	494	484	489
W6	489	460	475	475

.020 CSF DATA

	Trial #1	Trial #2	Trial #3	Average
A	221	234	240	232
B	212	218	240	223
C	251	234	268	257
D	200	195	218	204
E	216	204	220	213
F	234	230	225	230
L6	254	263	256	258
A	563	543	556	554
B	554	532	548	545
C	533	542	541	539
D	500	533	528	520
E	492	500	508	502
F	493	484	480	486
W6	454	460	443	452

.022" CSF DATA

	Trial #1	Trial #2	Trial #3	Average
A	210	214	217	214
B	233	251	224	236
C	208	213	209	210
D	204	198	210	204
E	221	205	220	215
F	231	248	229	236
L6	256	256	249	254

A	548	544	551	548
B	540	539	551	543
C	528	534	531	531
D	509	512	520	514
E	504	510	509	508
F	498	489	496	484
W6	452	459	465	459

.024 CSF DATA

	Trial #1	Trial #2	Trial #3	Average
A	225	228	234	229
B	236	224	230	230
C	209	218	225	217
D	210	228	215	218
E	225	233	218	225
F	230	240	245	238
L6	251	248	247	249
A	494	497	488	478
B	500	510	495	502
C	488	492	513	498
D	482	477	479	479
E	466	468	473	469
F	458	463	454	448
W6	438	442	445	442

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