FUNDAMENTALS OF DRYING: IMPULSE DRYING

Project F001

Final Report

to the

MEMBER COMPANIES OF THE INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

April 1999

INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

Atlanta, Georgia

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Report 14

A Final Progress Report

to the

MEMBER COMPANIES OF THE INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

By

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April 1999

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A. SUMMARY

In September 1998, 33# liner was produced on the #4 pilot machine under both single-felted wet pressing and impulse drying conditions. In October 1998, the pilot produced liner and commercial liner were converted to combined board and corrugated boxes at a commercial box plant. In January 1999, linerboard, medium, and combined board and box testing were completed.

The pilot trials demonstrated that 33# liner could be impulse dried at a reel speed of 380 m/min. Press dryness was improved by as much as 4 points, while CD STFI and CD ring crush were improved by more than 10%. Improvements to the smoothness of heated side of sheet were also realized.

Commercial box plant converting trials demonstrated that impulse dried linerboard can be used to increase ECT and box compression strength by as much as 10%. As anticipated, print quality was found to be superior.

A preliminary economic analysis was performed in which an impulse dryer would be installed on a dryer limited machine. It was assumed that the impulse dryer would increase press dryness by 4 points and would allow the basis weight to be reduced by 10%. The economic model showed that the 4 points in dryness would translate to a 17% tonnage increase. Applying the 10% basis weight reduction resulted in an increase in productivity, on an area basis, of 30%. The pulp cost savings was found to outweigh any additional electric power costs.

B. PILOT PRODUCTION TRIALS

B1.) Summary:

In September 1998, the Institute and Beloit Corporation were successful in impulse drying 161 g/m^2 (33#) linerboard on a one-meter wide pilot paper machine. This was the first time that impulse-dried linerboard had been reeled. The demonstration included a comparison of impulse drying to single-felted wet pressing.

Test results show that impulse drying, when compared to single-felted wet pressing, yields significant increases in press dryness, CD STFI, CD ring crush, and Mullen burst. The impulse-dried liner was also considerably smoother than the wet-pressed controls.

The demonstration also showed that runnability issues, such as start-up procedures, as well as operational issues, such as roll sticking and sheet delamination, have been resolved.

B2.) Background

Impulse drying has the promise of reducing capital costs, increasing machine productivity, reducing fiber use, reducing energy use, and improving paper physical properties. The Institute of Paper Science and Technology has been working to commercialize the impulse drying of board grades since the mid-1980s. In the early 1990s, the research focus was to control the physical aspects of the web to make it less susceptible to delamination, or to modify press roll surface properties to control heat flux. More recently [1,2,3], work has been undertaken to control the cause of delamination, i.e., flash vaporization.

In a unique experiment [1], Institute researchers showed that application of increased ambient pressure during and after the nip opening process inhibits sheet delamination. This result had significant implications for impulse drying commercialization. The work suggested that by sufficiently increasing the ambient pressure at nip opening, press roll surface temperature could be increased without inducing web delamination. In a general way, the work pointed out the importance of properly designing and controlling the nip opening process.

In subsequent research [2], temperature distributions were measured within layers of impulse-dried sheets during nip opening to various ambient pressures. Using these data and thermodynamic reasoning, pressure profiles were determined within the web. Based on these profiles, the hypothesis that delamination was caused by an imbalance of internal and external sheet pressure was tested. The results supported the view that delamination occurs when the pressure difference across the sheet is too high, and the buildup of internal pressure disrupts the sheet.

While opening the nip to ambient pressures in excess of one atmosphere may eventually prove to be practical, other methods that may be easier to implement were sought. In particular, subsequent laboratory experiments [3] showed that delamination could be inhibited by properly controlling the load applied to the sheet as the nip opens. The experiment consisted of identifying nip opening load conditions that would be sufficient to suppress the delamination of linerboard handsheets. The work demonstrated that delamination could be inhibited by applying a controlled decompression during nip opening.

Utilizing these discoveries, the Institute of Paper Science and Technology and the Beloit Corporation embarked on a joint project to develop impulse drying for application to board grades. The objectives of the project were to develop the necessary technology, to demonstrate the technology on a pilot paper machine, and to conduct converting trials at a commercial box plant.

In a recent paper [4], Institute and Beloit personnel described the process modifications that allow impulse drying of board grades to become commercially feasible and reported the results of initial pilot paper-machine experiments.

These initial pilot paper-machine experiments confirmed that the ramp decompression concept could be used to increase critical impulse drying temperature, thus opening the operating window of the technology. A specially designed adjustable ramp shoe allowed on-the-fly adjustment of nip decompression, which facilitated optimization. In addition, a combination of a specially designed press roll surface and the use of a TET doctor helped to eliminate picking and control sticking. Venting of the nip and blanket groove geometry were also found to be important.

B3.) Experimental

In September 1998, success was achieved in producing 33# linerboard on Beloit's #4 pilot paper machine. This is the first time that impulse dried linerboard had been reeled. The demonstration included a comparison of impulse drying to single-felted wet pressing. Figure B1 shows a schematic diagram of the press section of the pilot paper machine. The machine consisted of a gap former, bi-nip press, a shoe press, a dryer section, calender, and reel. The shoe press was of a closed design that could function as a single-felted wet press or as an impulse dryer. The shoe press was outfitted with a 0.23-m-long standard shoe followed by a 0.11-m-long ramp shoe. The pressure profile of the ramp shoe could be adjusted "on-the-fly" until the ramp profile was optimized to achieve the highest press roll temperature without experiencing sheet delamination. Figure B2 shows the ramp shoe pressure profile centered in the CD direction and measured from the position of peak load pressure. The profile is similar to that used in previously reported experiments on Beloit's No. 2 pilot paper machine [4].

Table B1 shows the chronology of the linerboard production trials. Reels of impulse-dried liner were produced at two press roll temperatures and two calender loadings on the first day. Press dryness measurements were also taken. On the second day, reels of single-felted wet-pressed liner at two calender loadings were produced. Measurements of press dryness were taken and calendering experiments were conducted to determine the impact of calender loading on linerboard properties. The second day was also used to repeat, over a range of press roll temperatures, the impulse drying that was accomplished on the first day.

Table B2 shows the paper-machine conditions that were recorded for the two days of the trial. Freeness was targeted at 650 ml CSF for both days. Note that the freeness during the first day was 613 ml CSF and during the second day was 669 ml CSF. This difference in refining level was inadvertent and was only discovered at the end of the second day of trials.

Table B3 shows web solids as measured after the couch, after the flatbox, and after the bi-nip press that was ahead of the impulse dryer.

Detailed measurements of the physical properties of the impulse-dried linerboard made at various press roll surface temperatures on the first and second day showed that they were slightly different. These differences are explored in the physical property development section of this paper.

B4.) Economics of Energy Usage

The electric power usage of the induction heating system was measured during the impulse drying experiments on both days. On the first day, while the reels were being produced, the induction heating system drew 495 kW at a roll temperature of 255°C and 531 kW at a roll temperature of 271°C.

Figure B3 shows the electric power usage as a function of average press roll surface temperature as measured on both days of the linerboard trials. Note that the energy usage on Day #1, during the reel production phase of the trial, was lower than on Day #2, when short duration experiments were conducted at increasing temperature. Note also that the later data are less consistent. This comparison suggests that the press roll was not in equilibrium during the later experiments.

Based on electric power usage data from Day #1, 171.5 kW-hr/ton were used when the roll was heated to a target roll temperature of 260°C. Based on an estimated electrical power cost of $0.03/kW-hr, our roll heating cost was $5.14/ton. The estimated cost savings in reduced steam usage (assuming a 3.8-point increase in dryness at the press section and a $2.83 million Btu steam cost) was $1.18/ton. Since some of the improvement in physical properties was due to increased refining, the estimated electric power costs associated with this incremental refining was $0.79/ton (based on an estimate of 26.3 kW-hr/ton to refine from 669 ml CSF to 613 ml CSF). Hence, the net increase in energy costs was about $4.75/ton. Therefore, to make this application viable, there must be fiber savings and productivity improvements that justify a $4.75/ton energy cost penalty.

B5.) Press Solids

Figure B4 shows press solids outgoing from the impulse dryer as a function of target roll surface temperature for experiments performed on the first and second day of the trials. Also included are the outgoing press solids for the wet pressing performed on Day #2 of the trials. As will be shown in the physical property development section, impulse drying temperatures of as high as 260°C could be reached without the sheet showing signs of sheet delamination. Hence, impulse drying could be used to increase outgoing solids by about 3.3 to 4.0 points of dryness as compared to the wet-pressed control.

B6.) Physical Property Development

Preliminary Measurements

Linerboard properties were measured at Beloit's paper testing laboratory. In these measurements, there was no attempt to distinguish cross-directional variations in paper physical properties. In addition, physical property indexes are based on average conditioned basis weight and no confidence limits were available. Based on the reported results, Figures B5 and B6 show CD STFI compression index and CD ring crush index, respectively, plotted against target roll surface temperature. Comparing impulse drying

(from the first day of the trial) to single-felted wet pressing (from the second day of the trial), there is [7] an 18% improvement in CD STFI and a 7% improvement in CD ring crush.

Finalized Measurements

Detailed measurement of linerboard properties was undertaken at the Institute of Paper Science and Technology. In these measurements, the linerboard was tested in three cross-directional lanes (operator lane, center, and drive lane). Test frequency was increased so that it would reduce the error bars (95% confidence limits) to an acceptable level. In addition, physical property indexes are based on oven-dried weights of individual test strips.

The cross-directional profile of the reels of linerboard produced on the first and second day of the trial was explored. Figure B7 shows CD SFTI index and Figure B8 shows MD STFI index, both as measured in the drive, center, and operator lanes of the single-felted wet-pressed and impulse-dried linerboard. The drive lane is presented as a white bar, the center lane is reported as a black bar, and the operator lane is shown as a gray bar. In Figure B7 the operator lane was normally stronger than the drive lane, which was in turn stronger than the center lane. In Figure B8 the operator lane was stronger than the center lane, which was stronger than the drive lane. This could be an artifact of cross directional nonuniformities (pressure, moisture, fiber orientation, and basis weight) associated with the setup of the paper machine. Figure B9 shows the MD/CD tensile ratio as measured in each of the three lanes. The web was consistently MD oriented (with an MD/CD tensile ratio of about 2.5) and tended to be more MD oriented in the center lane. The fact that CD STFI index tended to be lowest in the center lane suggests the need to also measure properties of corrugated board in edge and center lanes.

The data has been averaged over the web width in the remaining figures showing linerboard properties. In previous work, it was found that use of zd-ultrasonics is an effective and sensitive test for sheet delamination. Figure B10 shows the zd-specific elastic modulus of wet-pressed and impulse-dried linerboard as a function of the target roll surface temperature. Note that there was a drop-off in modulus at roll temperatures above 260°C. This suggests a critical impulse drying temperature of 260°C for the experiments.

Figures B11 and B12 show the CD STFI index and CD ring crush index, respectively, as plotted against target roll surface temperature. Both of these properties increase with increased roll temperature. It is important to compare these properties in a range of roll temperatures from 240 to 260°C on both days of the trial. It is observed that the strength of the impulse-dried liner produced on the first day of the trial tended to be stronger than that produced at a similar temperature on the second day. This can also be seen in Figure B13, where CD STFI index is plotted as a function of apparent density. Hence, the difference is attributed to increased refining on the first day.

While CD STFI compression strength and CD ring crush influence the ultimate strength of corrugated board, linerboard smoothness is most important as a predictor of printability [8]. In the present work, the smoothness of the roll side of the linerboard was measured as Bendtsen roughness and as Emveco roughness. Figure B14 reports the micro average Emveco roughness of the hot roll side of liner produced during our trials. Figure B15 reports the micro deviation Emveco roughness. In both cases the roughness in both the CD and MD were recorded. It is observed that the samples are always smoother in the MD. It is also observed that the samples become smoother as the roll surface temperature was increased and when the liner is calendered. The key finding is that

impulse drying significantly reduced the roughness of the linerboard and that impulse-dried liner would not need to be calendered.

In summary, Table B4 shows the percent improvement in critical physical properties of the reels of impulse dried linerboard as compared to the appropriate wet-pressed controls. Impulse drying was found to increase; CD STFI by about 10%, CD ring crush by between 11 to 14%, and Mullen burst by between 13 and 20%. Hence, basis weight reductions of 10% or more may be possible.

B7.) References

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4. Orloff, D. I. and Crouse, J. W., "Impulse Drying: Status of the Pilot-Scale Research Program," 1998 TAPPI Proceedings of the International Engineering Conference, Book 3, pp. 879-902, September 13-17, 1998.

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B8.) Acknowledgements

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B9.) Tables

Table B1. Chronology of Linerboard Production Trials

Day #	Reel Speed, m/min	Press Mode	Press Load, kN/m	Target Roll Temperature, °C	Calender Loading, kN/m	Comments
1	381	ID	1050	246	0 (open)	4 Reels produced
				246	35	2 Reels produced
				260	0 (open)	4 Reels produced
				205 to 262	n.a.	Dryness samples
2	381	SFWP	1050	n.a.	10-45	Reel samples
					0 (open)	4 Reels produced
					35	4 Reels produced
					n.a	Dryness samples
2	381	ID	1050	204 to 288	0 (open)	Reel samples
	381				n.a	Dryness samples
	314				n.a	Dryness samples

Table B2. Typical Production Conditions

Condition	Day 1	Day 2
Machine Chest Temp., °C	58	63
Freeness, ml CSF	613	669
WRV	2.15	2.05
Target Cond. Basis Wt, gsm	160	160
Jet-to-Wire Ratio	1.22	1.22
1st Press Load, kN/m	105	105
2nd Press Load, kN/m	140	140
Calender Temp., °C	121	121
Target Reel Moisture, %	5	5

Table B3. Typical Press Solids

Condition	Day 1	Day 2
After Couch, % Solids	20.2	21.0
After Flatbox, % Solids	23.5	24.5
After Bi-Nip, % Solids	40.4	42.0

Table B4. Percentage Improvement in Linerboard Properties
(Compared to the Wet Pressed Controls)

Impulse-Drying Temperature, ℃	Calendering	Improvement CD STFI, %	Improvement CD Ring Crush, %	Improvement Mullen Burst, %
246	no	9.8	11.4	17.1
260	no	9.7	11.4	13.2
246	yes	9.4	13.7	19.8

B10.) Figures

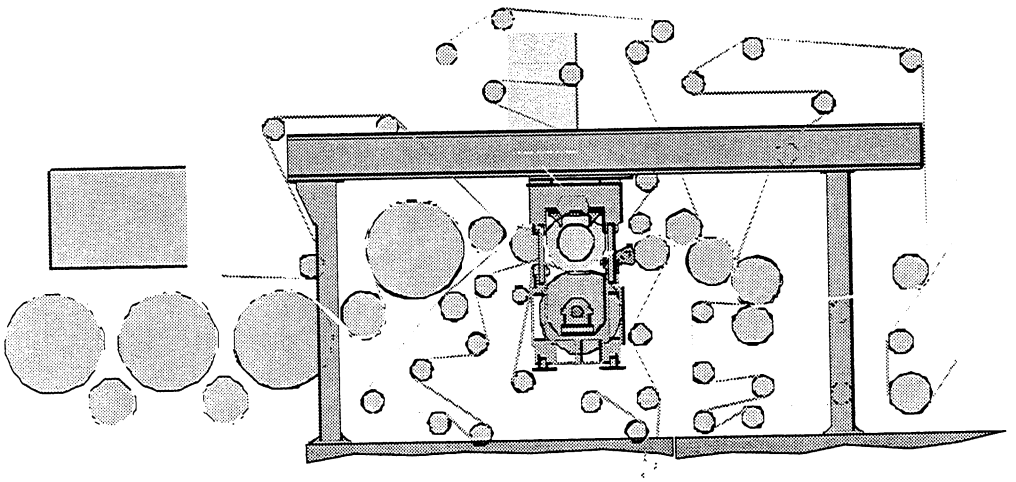

Figure B1. Press Section of the Pilot Paper Machine Showing the Impulse Dryer.

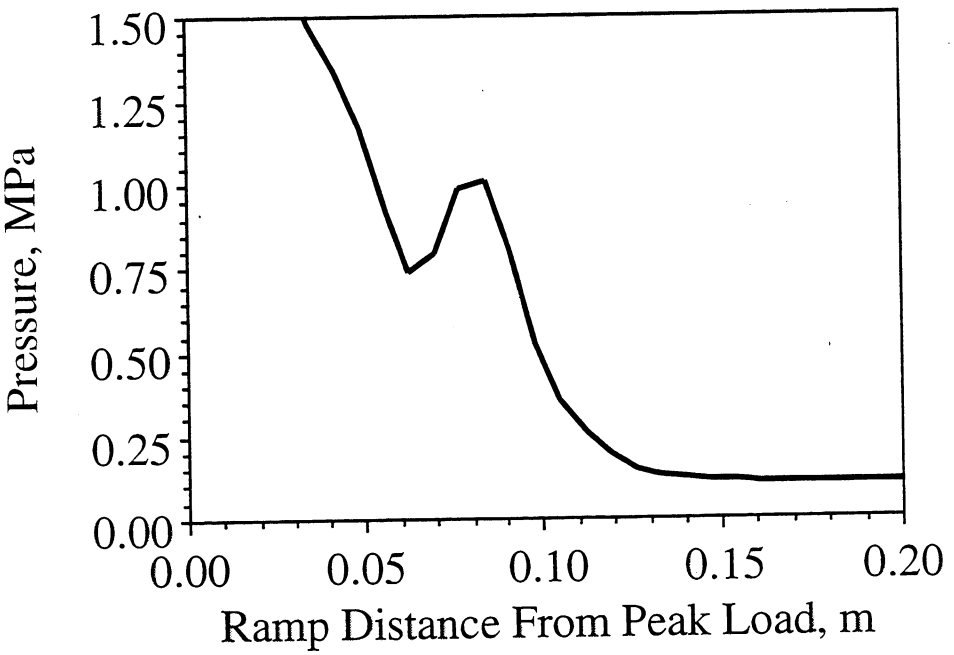

Figure B2. Ramp Pressure Profile.

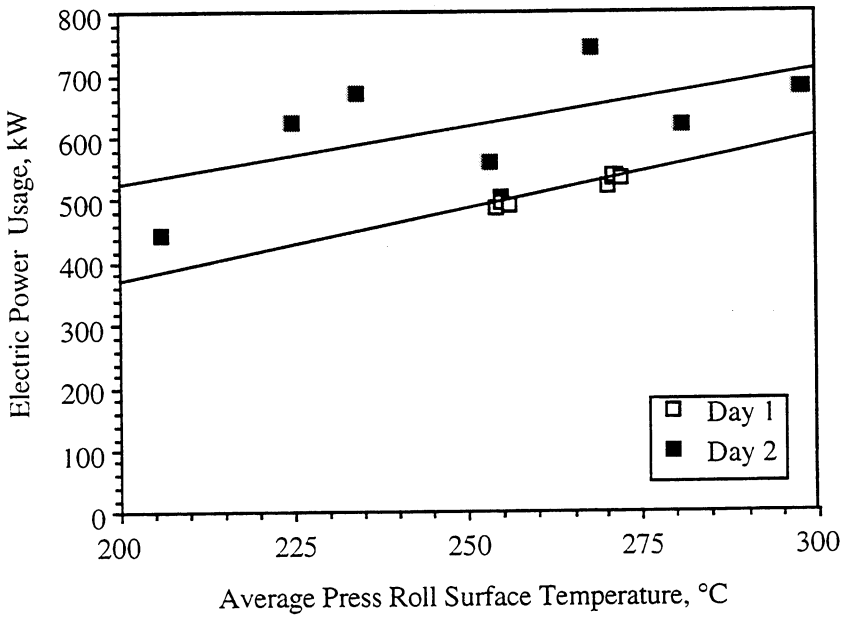

Figure B3. Electric Power Usage versus Average Press Roll Temperature.

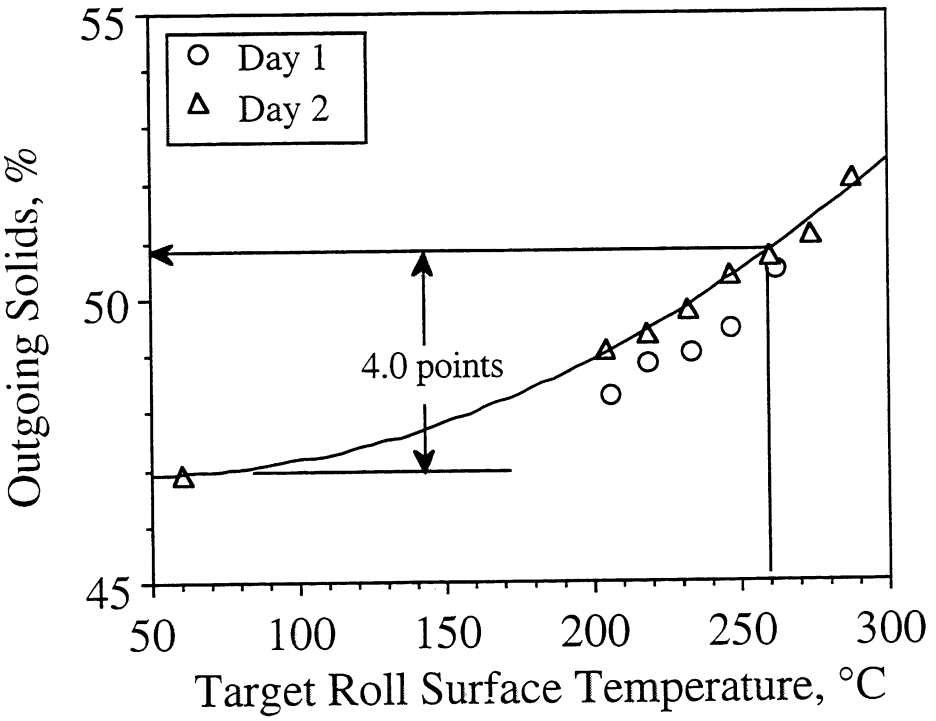

Figure B4. Outgoing Solids versus Target Roll Surface Temperature.

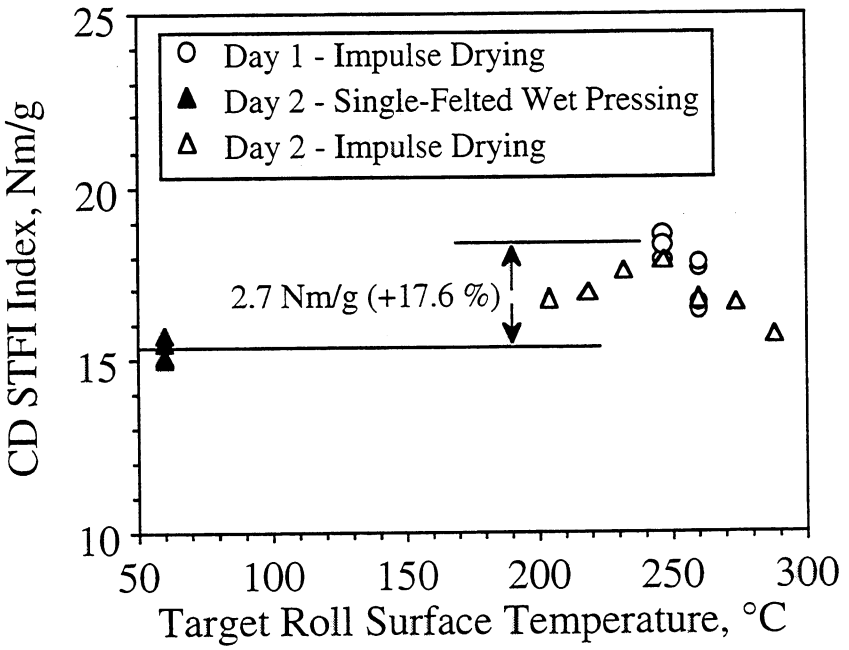

Figure B5. Cross-Directional STFI Compression Strength Index versus Target Roll Surface Temperature.

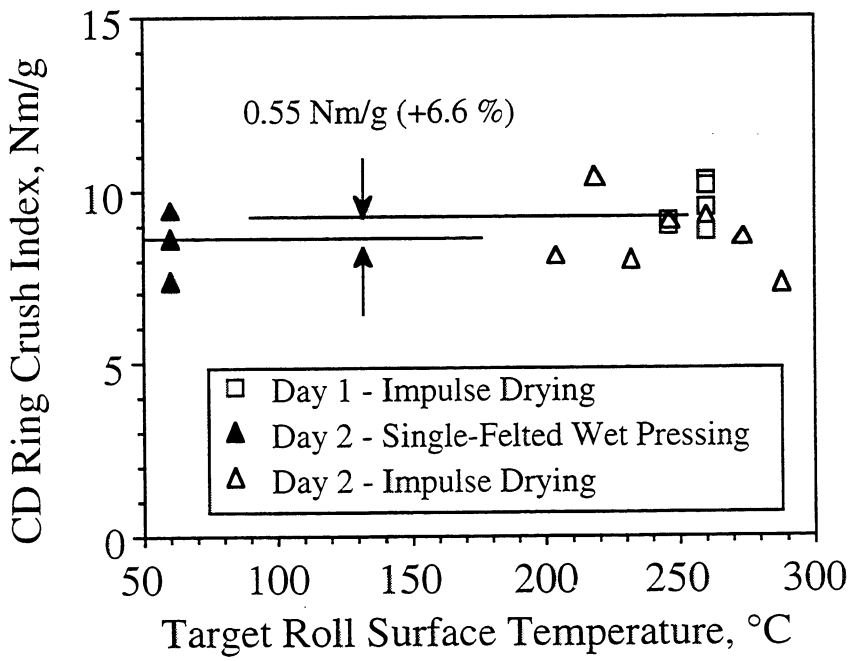

Figure B6. Cross-Directional Ring Crush Index versus Target Roll Surface Temperature.

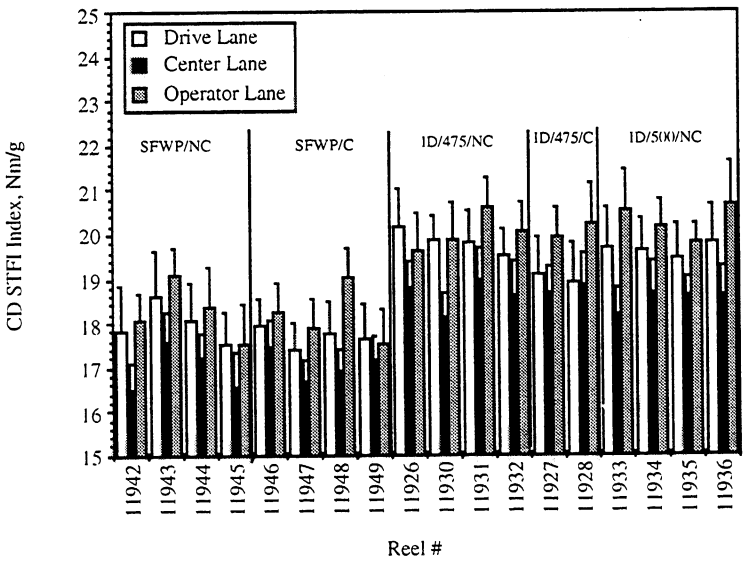

Figure B7. Cross-Directional STFI Index versus Reel Number

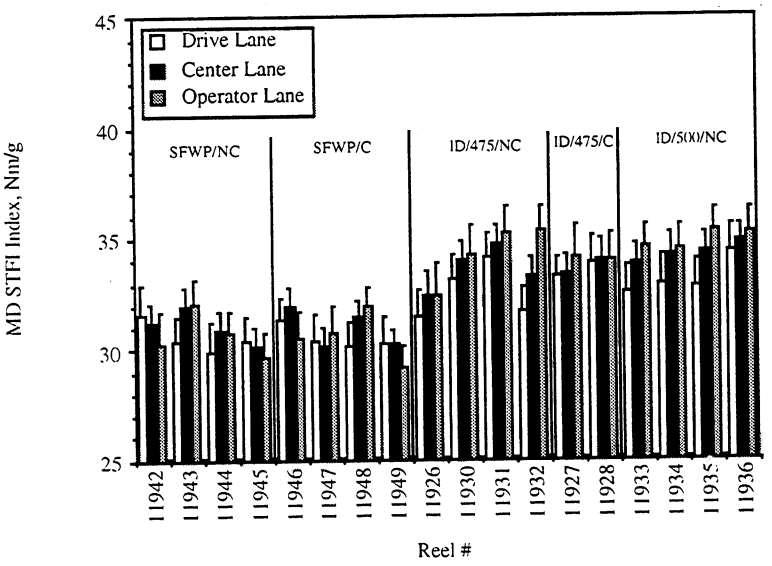

Figure B8. Machine-Directional STFI Index versus Reel Number

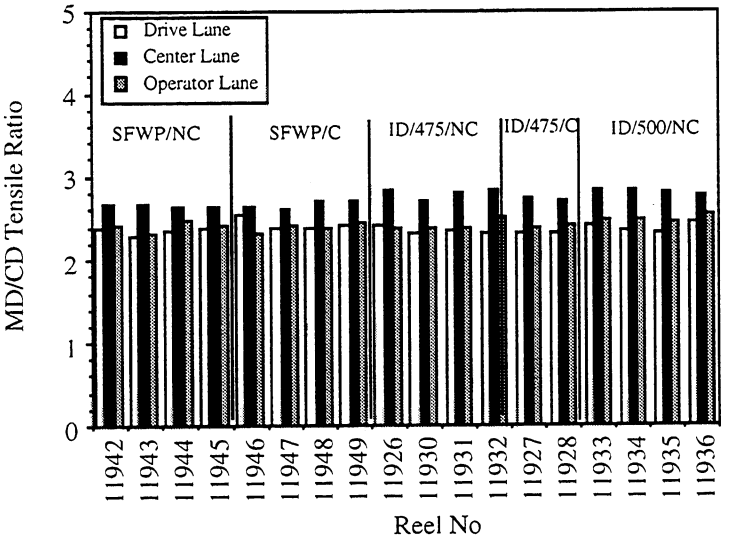

Figure B9. MD/CD Tensile Ratio Versus Reel Number

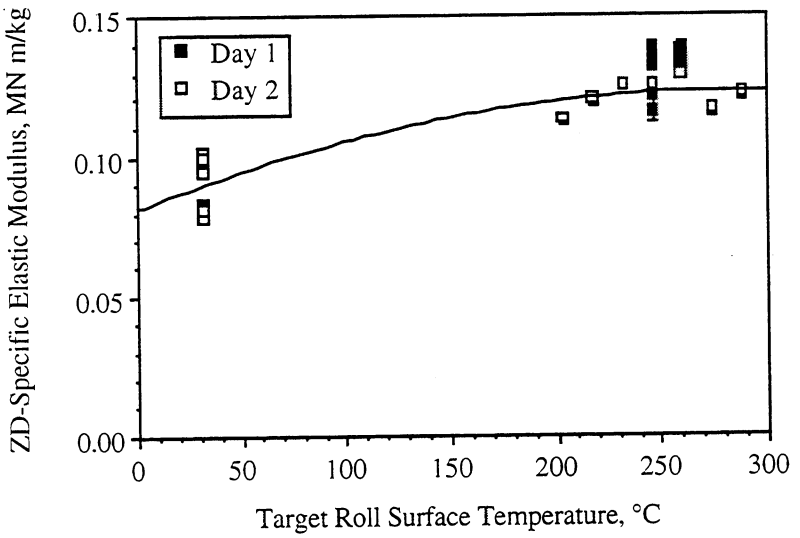

Figure B10. ZD- Specific Elastic Modulus versus Target Roll Surface Temperature.

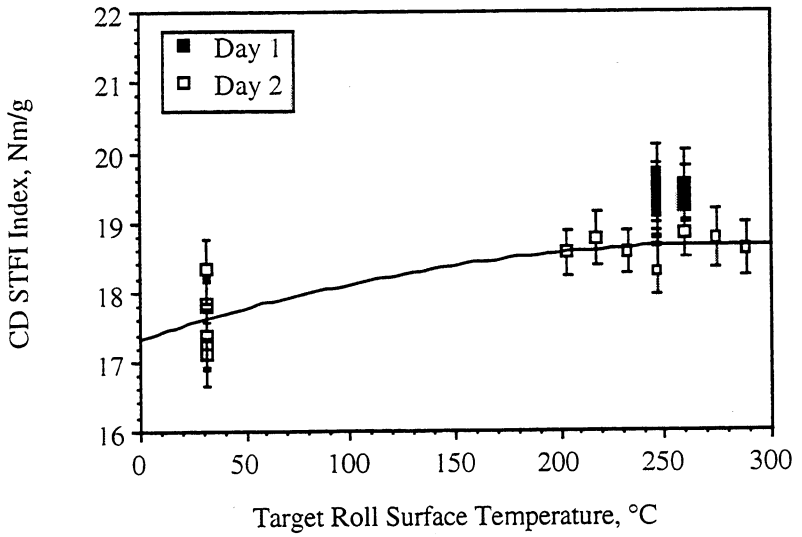

Figure B11. Cross-Directional STFI Compression Index versus Target Roll Surface Temperature.

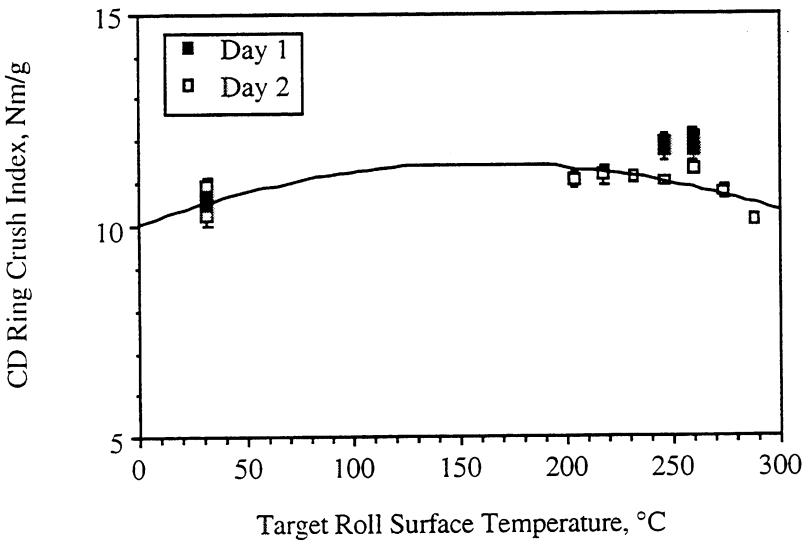

Figure B12. Cross-Directional Ring Crush Index versus Target Roll Surface Temperature.

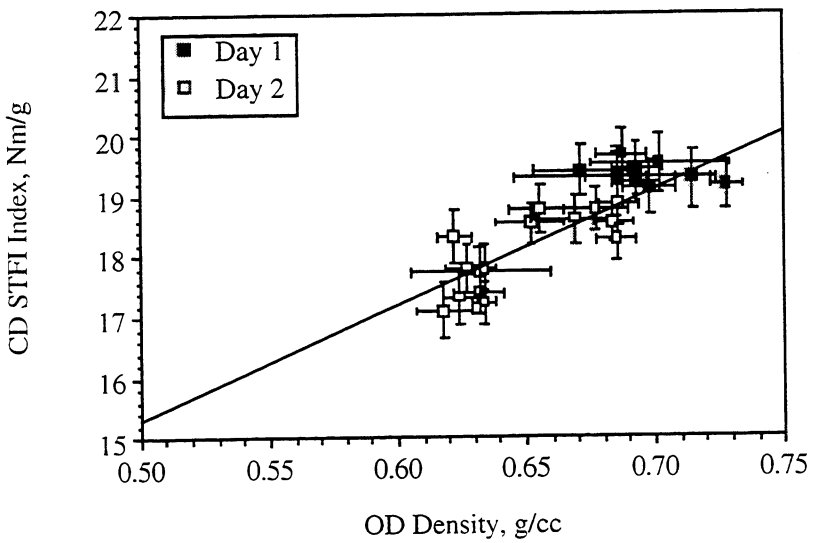

Figure B13. Cross-Directional STFI Compression Index versus OD Density.

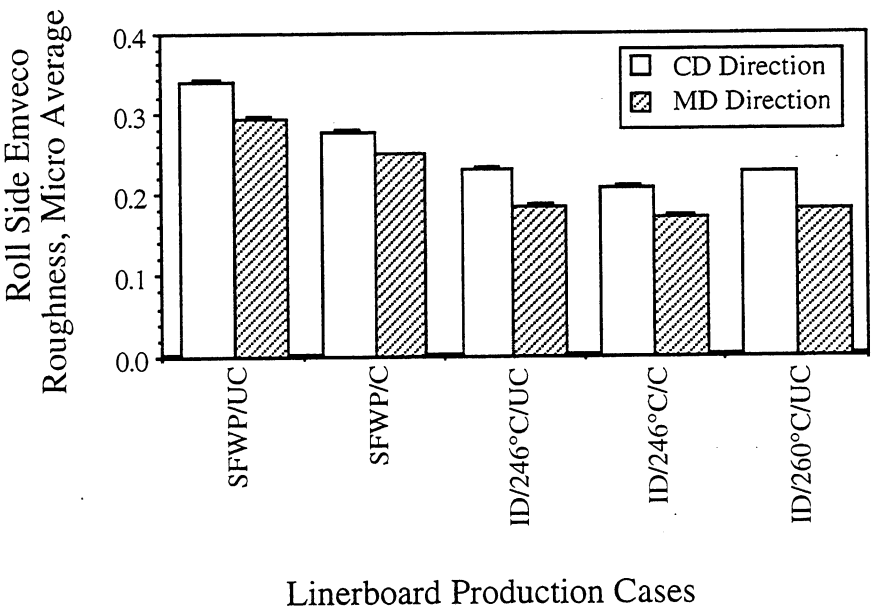

Figure B14. Micro Average Roll Side Emveco Roughness for Linerboard Production Cases.

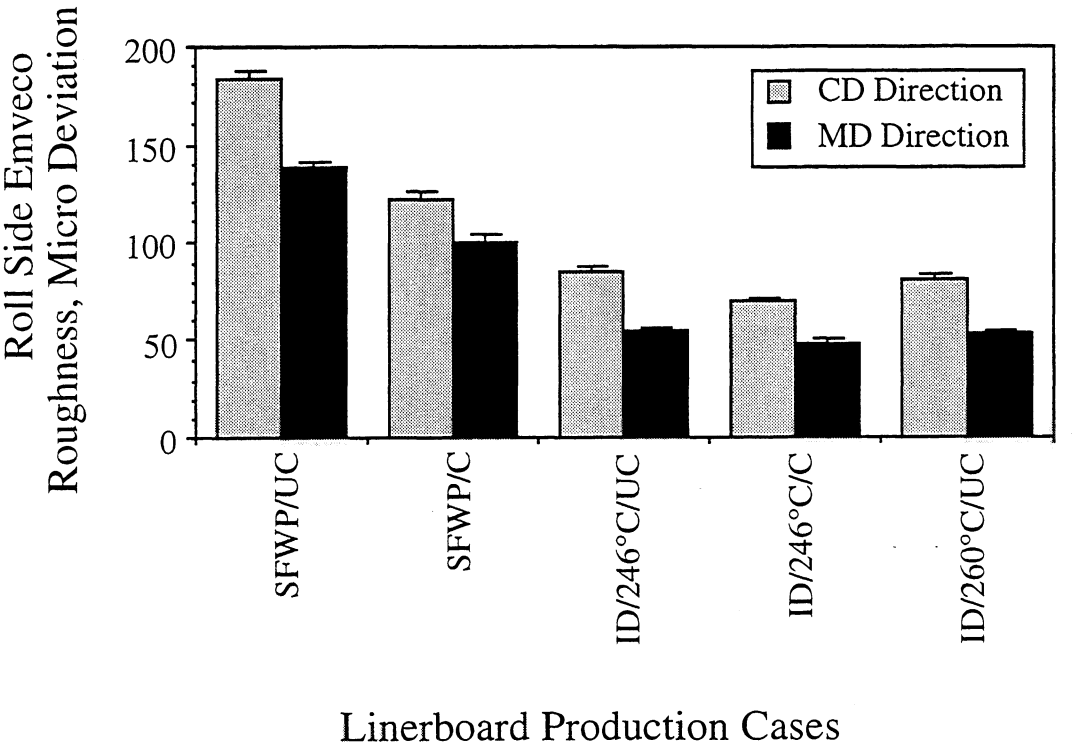

Figure B15. Micro Deviation Roll Side Emveco Roughness for Linerboard Production Cases.

C. CONVERTING TRIALS

C1.) Summary

Reels of linerboard produced on a pilot paper machine were converted on a commercial corrugator and the results compared to those obtained for a commercial liner. The pilot paper machine-produced liner included single-felted wet pressed liner as well as impulse dried liner.

The converting trials were conducted at the Stone Container plant in Keokuk, Iowa, in October 1998. The flexo, folder, gluer operation proceeded quite smoothly. In addition, there were no problems encountered during die cutting and no score cracking problems were noted. Finished containers were tested at the Institute for edge crush, flexural stiffness, pin adhesion, and box compression strength.

The performance of the impulse dried liner was compared to the single-felted wet pressed control as well as the commercial sample.

C2.) Experimental

The plan was to convert the Beloit 0.76 m (30 inch) wide rolls on a commercial corrugator to make combined board. Each run would produce a minimum of 1000 blanks, 1.52 m (60 inches) long and 0.69 m (27 inches) wide, from which 750 would be printed and converted into shipping containers and 250 blanks would be die cut and not printed. The resulting single-wall container would be 0.38 m (15 inches) long, 0.36 m (14 inches wide), and 0.30 m (12 inches) high.

A printing plate was selected for printing comparisons. The print copy included an Institute of Paper Science and Technology letterhead logo that was enlarged to 0.15 m (6 inches) in diameter. It also included conventional halftones of Edgar Allen Poe; lines, from 1/2 point to 8 point; portions of UPC and shipper UPC; and a heliograph of a child car seat.

A number of container plants were contacted to determine if they could run five sets of narrow 0.76 m (30 inch) wide rolls to produce combined board, as well as print and produce containers from impulse dried 161 g/m^2 (33#) kraft linerboard made on Beloit pilot paper machine. One set of 161 g/m^2 (33#) commercial kraft liner in any roll of their plant inventory would also be run. Each of the six runs would have a maximum of 3048 lineal meters (10,000 lineal feet). If the runs on the corrugator went smoothly, it could be shortened to 1524 lineal meters (5000 lineal feet).

The results from the inquiries were not encouraging at first; however, we eventually were fortunate to receive a positive response from the Stone Container plant in Keokuk, Iowa. Converting trials were conducted in October 1998.

Tables C1 through C3 show specific details of the three unit operations performed at the box plant. The corrugator crew had been fully informed and coached by the plant manager in advance of the run and the implementation of the actual run went very smoothly. The single-facer and double-backer splicers were loaded with appropriate rolls in the planned sequence and when 305 lineal meters (1000 lineal feet) had been produced, the splicers were manually turned on starting the next sequence. The commercial rolls of 161 g/m^2 (33#) liner were run as a wider roll, 1.689 m (66.5 inch), from the plant inventory. The corrugating medium, 1.686 m (66.375 inch) wide, came from the same lot as the 0.759 m (29.875 inch) wide rolls used for the Beloit pilot liner.

Table C4 identifies the liner used in each of the corrugator cases. Corrugator case 1 was conducted with commericial linerboard. Corrugator cases 2A, 2B, 4, and 6 used impulse-dried liner while cases 3 and 5 used the single-felted wet pressed control. The same medium was used for all corrugator cases. Note that case 2A and 2B were produced from different reels produced at the same nominal conditions. Table C5 shows some pertinent physical properties of the liner and medium used in each case.

The flexo, folder, gluer operation also proceeded quite smoothly after adjusting for proper ink coverage and printing pressure on all six sets of blanks. Finished containers were placed on pallets, shrink wrapped for final shipment, and tested at the Institute.

No problems were observed in the die cutting operation, and no score cracking problems noted in MD, CD, or angle scores.

C3.) Results

Combined board and boxes produced for each case were numbered in the order of corrugating prior to the initiation of testing. Four sequential sets of samples were taken from each of the cases, resulting in a total of 28 sample sets.

Lane and Sequence Effects

Lane-specific testing of the liner demonstrated a CD profile in each of the reels produced on the Beloit pilot machine. The center lane typically was found to exhibit lower strength. It was therefore important to test the combined board in both the center and edge lanes for edge crush, caliper, and pin adhesion. The results of these tests are plotted versus corrugator sequence in Figures C1 through C4.

In Figure C1 the edge crush as measured in the center lane was typically lower than that measured on the edges for cases 2A through 6. This is consistent with the lower STFI compression strength and ring crush of the center lane of the liner. The edge crush of case 1, the commercial control, was position independent, as expected.

In Figure C2 the caliper of the combined board is reported for both the center and edges of the samples. There was a slight tendency for the center to be of lower caliper than the edges.

Single-facer pin adhesion data is reported in Figure C3. There was no observed bias regarding test position as the results in the center are similar to those on the edges. Double-backer pin adhesion data is reported in Figure C4. Here, the pin adhesion strength in the center was typically higher than at the edges. This was also true for the commercial control. Hence, it is probable that this bias was due to converting equipment rather than the liner.

Figure C5 shows the flexural stiffness of the combined board as measured in both the MD and CD directions. Due to the size of the test specimen, only the center was tested.

Figure C6 shows the peak load as measured during top-to-bottom box compression testing. Note that case 6 could not be included as we only made combined board blanks and did not make boxes in this case. Figure C7 shows the deflection at peak load as measured during the box compression testing.

Case Effects

In Figures C8 through C14, the four sequential sets in each case are pooled together to obtain average properties per case. Figure C8 shows that the highest edge crush values were obtained for cases 1, 2A, 2B, and 4, while the lowest edge crush values were obtained in cases 3, 5, and 6.

Figure C9 shows that the commercial liner yielded combined board with the highest caliper, while board made from the pilot produced reels were of consistently lower caliper.

Figure C10 shows that the highest single-facer pin adhesion values were obtained for cases 3 and 5 where the single-felted wet pressed liner was utilized. Pin adhesion for the impulse dried cases were lower but consistent with that obtained using the commercial liner, see case 1. Figure C11 shows that the double-backer pin adhesion for board made from the pilot-produced liner was at least as strong as that obtained from the commercial sample, case 1.

Figure C12 shows that the flexural stiffness was increased when the liner was impulse dried. Further analysis (see below) shows that this was related to increases in Young's modulus of the impulse dried liner.

Figure C13 shows an improvement in box compression strength for the impulse dried cases 2A, 2B and 4 as compared to the wet pressed control cases 3 and 5. The impulse dried cases are a least as strong as the commercial control. Boxes made from liner impulse dried at the highest temperature were superior in strength to those made from the wet pressed control as well as the commercial control.

Figure C14 shows that box deflection at peak load was fairly independent of case.

Table C6 shows the average edge crush, combined board caliper, and single-facer and double-backer pin adhesions for each case. Table C7 shows the percentage change for each of these as compared to the corresponding wet-pressed control. It is observed that impulse drying resulted in as much as a 10.6% increase in edge crush, a decrease in single-facer pin adhesion of as much as 27.3%, and an increase in double-backer pin adhesion of as much as 9.5%.

Table C8 shows the average peak load from top-to-bottom, end-to-end, and side-to-side box compression testing, as well as the MD and CD flexural stiffness of the combined board. Table 2-9 reports the percent change of these properties as compared to the appropriate wet pressed control. Impulse drying resulted in as much as a 10.3% increase in top-to-bottom box compression strength.

Visual inspection of the printed boxes showed significant improvement to print coverage. Impulse dried samples had superior print quality to boxes made from the wet pressed control liners as well as those made from the commercial liner.

C4.) Discussion

Box Compression Strength

In 1963 McKee [1] published an equation which could be used to predict box compression strength as a function of edge crush strength, flexural stiffness, and box perimeter.

The McKee equation is,

$$P = 2.028\ (P_m)^{0.746}\ (D_x D_y)^{0.127}\ (Z)^{0.492} \qquad \{1\}$$

Where,

P = Box Compression Strength, lb
P_m = Edge Crush Test Strength, lb/in
D_x = MD Flexural Stiffness, lb-in
D_y = CD Flexural Stiffness, lb-in

Z = Box Perimeter, in

Based on the powers in the McKee formula, it is recognized that edge crush strength plays a dominant role in determining box compression strength. Flexural stiffness and box perimeter play lesser roles.

Edge Crush

For two grade ranges, Witsitt [2] has suggested equations for predicting edge crush from the ring crush of liner and medium used to manufacture corrugated board. These are given as,

ECT Grades 23-32 lb/in:

$$P_m = 0.80\ (2L + tM) + 12 \qquad \{2\}$$

ECT Grades 38-60 lb/in:

$$P_m = 1.27\ (2L + tM) - 6 \qquad \{3\}$$

Where,

L = CD ring crush of the linerboard, lb/in
M = CD ring crush of the medium, lb/in
t = draw or take-up factor
A-flute = 1.55
B-flute = 1.36
C-flute = 1.42

Whittsit also suggests an equation to predict edge crush from STFI compression strength,

$$P_m = 0.545\ (2L_s + tM_s) + 4.785 \qquad \{4\}$$

Where,

L_s = CD STFI compression strength of the linerboard, lb/in
M_s = CD STFI compression strength of the medium, lb/in

Hence, assuming that corrugating conditions are normal, we can predict edge crush from linerboard and medium strength properties. If corrugating process variables deviate from normal practice, edge crush may also depend on these corrugating variables. Along these lines, Batelka [3] has developed a correlation for edge crush in terms of some box plant process variables. For the range of his experiments, the correlation was,

$$P_m = 33.7 - a\ (A) + b\ (B) - c\ (C) - d\ (D) - e\ (E) \qquad \{5\}$$

Where,

a =	0.0397,	A =	Leaning Flute Angle, degrees
b =	0.1500,	B =	Single-Face Pin Adhesion, lb
c =	0.0534,	C =	High/Low Flutes @ 4 mils or Greater, %
d =	0.1340,	D =	Actual Crushing, mils
e =	0.1300,	E =	Pressure Roll Cutting, % Mullen Loss

from the coefficients we see that single-face pin adhesion, flute crushing, and pressure roll cutting are the dominant factors.

Flexural Stiffness

Based on Whittsit's work [2] we can get additional insight into edge crush by exploring how flexural stiffness is related to the properties of the linerboard and medium as well as the geometry of the combined board. Whittsit gives the following equations as approximations,

$$D_x = E_{xf}\, T\, H^2/2 \qquad \{6\}$$

$$D_y = E_{yf}\, T\, H^2/2 + E_{ym}\, I \qquad \{7\}$$

Where,

Dx, Dy	= Flexural stiffness in the MD and CD directions, lb-in
E_{xf}, E_{yf}	= Young's modulus of the linerboard in the MD and CD directions, lb/in^2
T	= Average linerboard thickness, in
H	= Combined board thickness, in
E_{zm}	= Young's modulus of the medium in the CD direction, lb/in^2
I	= Moment of inertia of the flute, in^4/in

In these equations, MD flexural stiffness is primarily dependent on the Young's modulus of the linerboard and the combined board caliper. In the CD direction, the flexural stiffness is dependent on the Young's modulus of the linerboard and the medium as well as the moment of inertia of the flute.

Predicting Box Compression From Linerboard Properties

Assuming normal corrugating conditions, box compression strength, P, may be expressed as,

$$P = 2.028\ (P_m)^{0.746}\ (D_x D_y)^{0.127}\ (Z)^{0.492} \qquad \{1\}$$

In our experiments we have produced linerboard that has different properties than conventional linerboard. We expect the following properties of the linerboard to have changed; L, E_{xf}, E_{yf}, and T. Since the linerboard thickness changes, so will H, the combined board caliper. Using Equations {1}, {2}, {6} and {7}, the change in P may be calculated from measured changes in L, E_{xf}, E_{yf}, T, and H. By differentiation of P, we obtain,

$$\Delta P = (\delta P/\delta L)\,\Delta L + (\delta P/\delta Exf)\,\Delta E_{xf} + (\delta P/\delta E_{yf})\,\Delta Eyf + (\delta P/\delta T)\,\Delta T + (\delta P/\delta H)\,\Delta H \qquad \{8\}$$

Taking the partial derivatives,

$$(\delta P/\delta L) = 1.1936 \{P/P_m\} = \{1.1936/(0.80\ (2L+tM)+12)\}\ P \quad \{9\}$$

$$(\delta P/\delta Exf) = 0.0635 \{TH^2/D_x\}\ P = \{0.127/E_{xf}\}\ P \quad \{10\}$$

$$(\delta P/\delta E_{yf}) = 0.0635 \{TH^2/D_y\}\ P = 0.0635 \{TH^2/(E_{yf}(TH^2/2)+E_{ym}I)\}\ P \quad \{11\}$$

$$(\delta P/\delta T) = \{0.254/T\} \{(E_{yf}H^2T+E_{ym}I)/(E_{yf}H^2T+2E_{ym}I)\}\ P \quad \{12\}$$

$$(\delta P/\delta H) = 0.508 \{(E_{yf}H^2T+E_{ym}I)/(E_{yf}H^3T+2E_{ym}HI)\}\ P \quad \{13\}$$

Based on the linerboard data and the above equations, Table C10 was constructed.

Here we have assumed that the following properties were constant;

M	= 5.10 lb/in
E_{ym}	= 10222 lb/in^2
t	= 1.42
I	= 0.0002863 in^4/in, (estimated, see [4])

From Table C10, the theory predicts that use of the impulse dried linerboard would yield a 17.14 lb increase in box compression strength compared to the case where the wet pressed linerboard was used. Most of the increase comes from the increase in ring crush with smaller increases from the Young's modulus terms. It is noted that the reduced linerboard thickness yields a negative contribution to box compression strength that is less than half of the magnitude of the ring crush term. It is also noted that, in actuality, we measured an increase in box compression strength of 42.72 lb. The discrepancy with the theory may result from the fact that the equations used are based on correlations. In any case, impulse drying yielded higher box compression strength because of the increase in ring crush (or STFI) and to a lesser extent from increases in Young's modulus of the linerboard.

Pin Adhesion Strength

In Equation {5} we saw the importance of pin adhesion as a corrugation variable. Hence, we present a brief summary of some key points in the literature on pin adhesion.

According to Daub [5], glueability is the ability of paper to anchor and to permit setting of the glue, which is determined by the setting mechanism. For starch glue, the setting mechanism is gelatinization, which requires heat and water. The main parameters of the gluing process are the amount of glue applied (or spread), the joining pressure, heat, and the open time and closed time as determined by web speed. He reports that the paper properties which probably affect the glueability are basis weight, apparent density, moisture content, porosity, absorbency, thermal conductivity, surface energy, and roughness. The absorbency behavior of paper is different for glue and water. Looking at it another way, it also depends on the capillary forces and external pressure.

Highton [6] has presented a theoretical analysis of the physical conditions to which fluted medium is subjected as it passes through a single-facer. He states that the critical part of the single-facer process is the impact of the pressure roll forcing the liner against the glued flute tip of the fluting medium. The openness, density, and compressibility of the

linerboard and medium determines how far the glue is forced into the fluting medium and liner and how much of the glue is squeezed out onto the shoulders of the flute. The density and compressibility of the liner and medium also control how much heat from the corrugator roll and pressure roll is conducted into the glue zone of the joint.

Lepoutre [7] has reviewed the principles of adhesion and has examined the main aspects of glueability at the corrugator. He reports that penetration at the single-facer is mainly a function of pressure. While pressure plays a much less important role in penetration at the double-backer.

Rutherford [8] has reported on the effect that the use of high-performance (high-density) liners has had on pin adhesion. He states that the downside of high-performance liners is that densification leads to fewer and smaller openings in the surface of the sheet. Thus, it becomes difficult for the corrugating adhesive to work its way into the surface. Such paper will be more difficult to bond, producing shallow surface bonds, at best, if corrugating conditions are not altered.

Wallace [9] has found that high-performance liners, with their increased density and reduced moisture content, offer improved ring crush. However, because of their increased density and reduced moisture content, they are more prone to overheating, poor adhesive interaction, and dry cracking. These high-performance liners are produced on paper machines with extended nip presses. With these presses, and as press loading is increased, the sheet becomes more compressed, and interfiber bonding (hydrogen bonding) improves. The sheet becomes tighter and denser, resulting in higher ring crush values. However, the increased density also affects other properties of the paper. High-density liners have closer fibers, making the sheet much less porous than conventional kraft papers. Reducing porosity in the sheet increases the potential of bonding problems because of poor adhesive penetration. In addition, the moisture content of the high-performance liners is typically lower than conventional kraft liners (4 to 4.5% compared to 8 to 9%). In addition, with closer fiber contact and less insulating air space, heat easily passes through high-density paper. Thus these liners become hotter more quickly than conventional liners. Wallace reports that these problems can be overcome by adding moisture to the liner and medium and by careful control of temperature.

In the box plant trial, the single-facer pressure was set by fixing the clearance between the pressure roll and the upper corrugator roll. Hence, the actual applied pressure increased with increased caliper of the liner, and single-facer pin adhesion decreased with decreased caliper or increased apparent density as we have observed (see Figure 2-15). Hence, we expect that we could have increased single-facer pin adhesion of the impulse dried cases by suitable adjustment of pressure.

C5.) References

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C6.) Acknowledgements

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C7.) Tables

Table C1. Corrugating Conditions

Manufacturer	Langston
Type	XD
Width	2.21 m (87 inch)
Run Speed	121.9 m/min (400 ft/min)
Liner Width	0.762 m (30 inch)
Liner Basis Weight	161 g/m^2 (33 lb/msf)
Medium Width	0.759 m (29.875 inches)
Medium Type	40% nonsulfur - 60% OCC
Medium Basis Weight	126 g/m^2 (26 lb/msf)
Starch for Single-facer	modified pearl, 26% solids, 62.2°C (144°F) Gel Point
Starch for Double-backer	20% cooked, 80% raw, 26% solids, 64.4°C (148°F) Gel point
Anilox roll	1.378 lines/mm (35 lines/inch)

Table C2. Printing Conditions

Manufacturer	Ward Machinery
Width	1.27 m (50 inch) x 2.79 m (110 inch)
Blank size	1.52 m (60 inch) x 0.69 m (27 inch)
Speed	80 kicks per minute
Ink	GCMI black (Borden Chemical Co.)
Anilox	6.299 lines/mm (160 lines/inch)

Table C3. Die Cutting Conditions

Manufacturer	United Container Machinery Group
Size	1.27 m (50 inch)

Table C4. Identification of Liner and Medium Used

Paper Type	Third Press Type	Impulse Drying Temperature, ℃	Calendering	Used In Case Number
Liner	Commercial			1
Liner	Impulse-Dried	246	no	2A
Liner	Impulse-Dried	246	no	2B
Liner	S.F. Wet Press		yes	3
Liner	Impulse-Dried	260	no	4
Liner	S.F. Wet Press		no	5
Liner	Impulse-Dried	246	yes	6
Medium	Commercial			1-6

Table C5. Physical Properies Of The Liner And Medium

Case	O.D. Basis Weight, g/m^2	Soft Caliper µm	CD STFI Index, Nm/g	CD Ring Crush Index, Nm/g	Burst, KPa	Printed Side Emveco Roughness, Micro Deviation
Liner - 1	147	210	21.6	12.0	574	184
Liner - 2A	150	218	19.4	11.9	539	85
Liner - 2B	150	218	19.4	11.9	539	85
Liner - 3	151	238	17.6	10.4	445	123
Liner - 4	150	218	19.4	11.9	521	81
Liner - 5	152	246	17.6	10.7	460	184
Liner - 6	150	208	19.2	11.8	533	69
Medium - (1-6)	115	185	16.6	7.7	243	n.m.

Table C6. Combined Board Properties

Case No.	Average Single-Face Pin Adhesion, N/m	Average Double-Back Pin Adhesion, N/m	Average Combined Caliper, mm	Average Edge Crush, kN/m
1	589	606	3.995	5.230
2A	534	693	3.810	5.095
2B	557	740	3.680	5.125
3	660	729	3.725	4.640
4	565	642	3.710	5.075
5	735	677	3.765	4.635
6	599	699	3.605	4.685

Table C7. Percent Change Compared To Wet Pressed Control

Case No.	Average Single-Facer Pin Adhesion, & Change	Average Double-Facer Pin Adhesion, % Change	Average Edge Crush, % Change
1			
2A	-27.3	2.4	9.9
2B	-24.2	9.3	10.6
3			
4	-23.1	-5.2	9.5
5			
6	-9.3	-4.1	1.0

Table C8. Combined Board and Box Properties

Case No.	MD Flexural Stiffness, Nm	CD Flexural Stiffness, Nm	Top-to-Bot Box Compr. Peak Load, kN	End-to-End Box Compr. Peak Load, kN	Side-to-Side Box Compr. Peak Load, kN
1	9.83	4.97	1.99	1.27	1.62
2A	8.70	4.32	2.00	1.36	1.64
2B	9.12	3.92	2.04	1.17	1.54
3	8.90	3.57	1.85	1.26	1.44
4	9.82	4.30	2.14	1.41	1.76
5	8.82	3.80	1.94	1.33	1.67
6	8.80	4.04	Not avail.	Not avail	Not avail.

Table C9. Percent Change Compared To Wet Pressed Control

Case No.	MD Flexural Stiffness, % Change	CD Flexural Stiffness, % Change	Top-to-Bot Box Compr. Peak Load, % Change	End-to-End Box Compr. Peak Load, % Change	Side-to-Side Box Compr. Peak Load, % Change
1					
2A	-1.36	13.68	3.09	2.25	-1.79
2B	3.40	3.16	5.15	-12.03	-7.78
3					
4	11.34	13.16	10.31	6.01	5.39
5					
6	-1.12	13.17	Not avail.	Not avail.	Not avail.

Table C10. Measured and Predicted Change In Properties

Property	Wet Press Control (case 3)	Impulse Dried (case 2B)	Measured Change Δ(Property)
L, kN/m or (lb/in)	1.57 (8.97)	1.78 (10.17)	0.21 (+1.20)
Exf, MN/m or (lb/in^2)	360.5 (52292)	375.7 (54483)	15.2 (+2191)
Eyf, MN/m or (lb/in^2)	132.3 (19189)	146.4 (20957)	14.1 (+1768)
T, mm or (in)	0.24 (0.0094)	0.22 (0.0086)	-0.02 (-0.0008)
H, mm or (in)	3.73 (0.1470)	3.68 (0.1450)	-0.05 (-0.0020)
P, kN or (lb)	1.85 (415.9)	2.04 (458.61)	0.19 (+42.71)
$(\delta P/\delta L)\Delta L$, kN or (lb)	0.082 (+18.53)		
$(\delta P/\delta E_{xf})\Delta E_{xf}$, kN or (lb)	0.010 (+2.21)		
$(\delta P/\delta E_{yf})\Delta E_{yf}$, kN or (lb)	0.009 (+1.94)		
$(\delta P/\delta T)\Delta T$, kN or (lb)	-0.028 (-6.21)		
$(\delta P/\delta H)\Delta H$, kN or (lb)	0.003 (+0.67)		

C8.) Figures

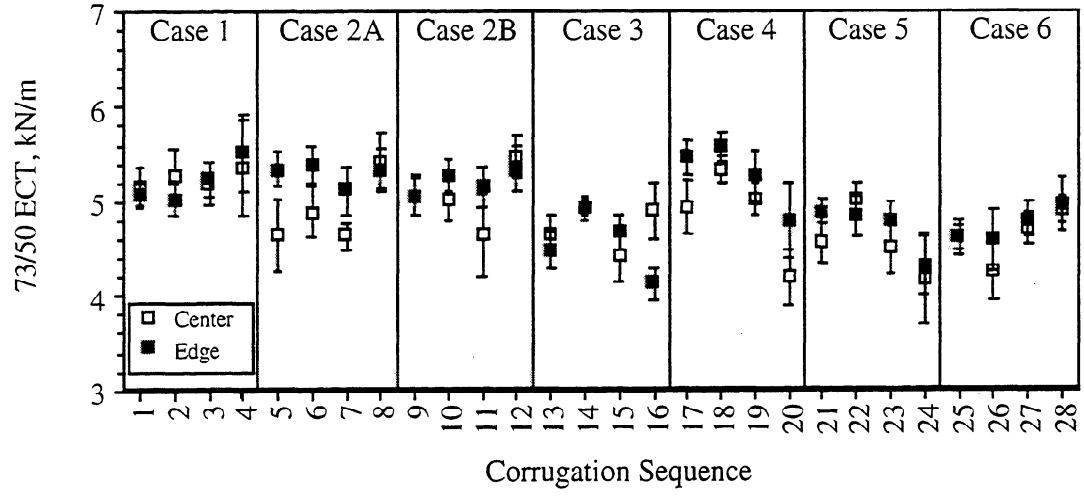

Figure C1. Edge Crush Test Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Sequence.

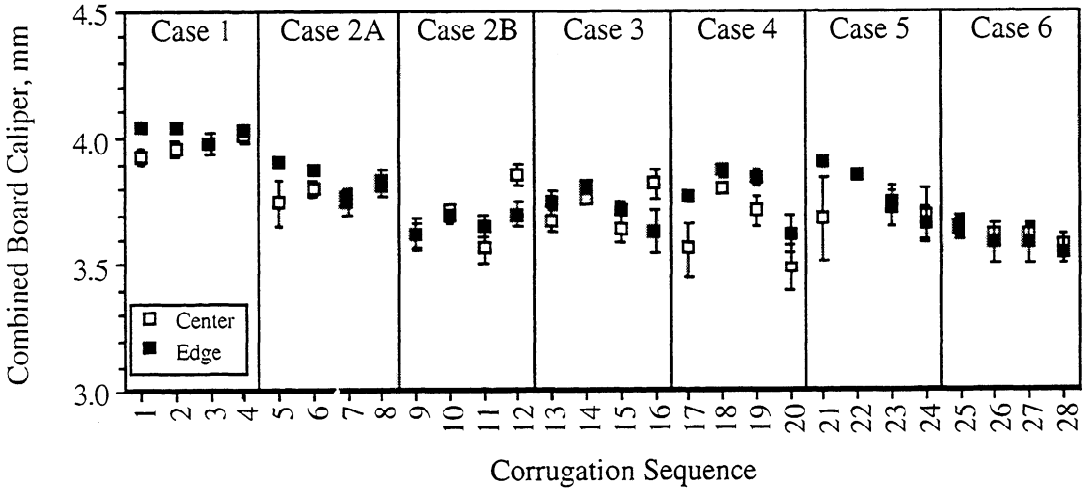

Figure C2. Caliper Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Sequence.

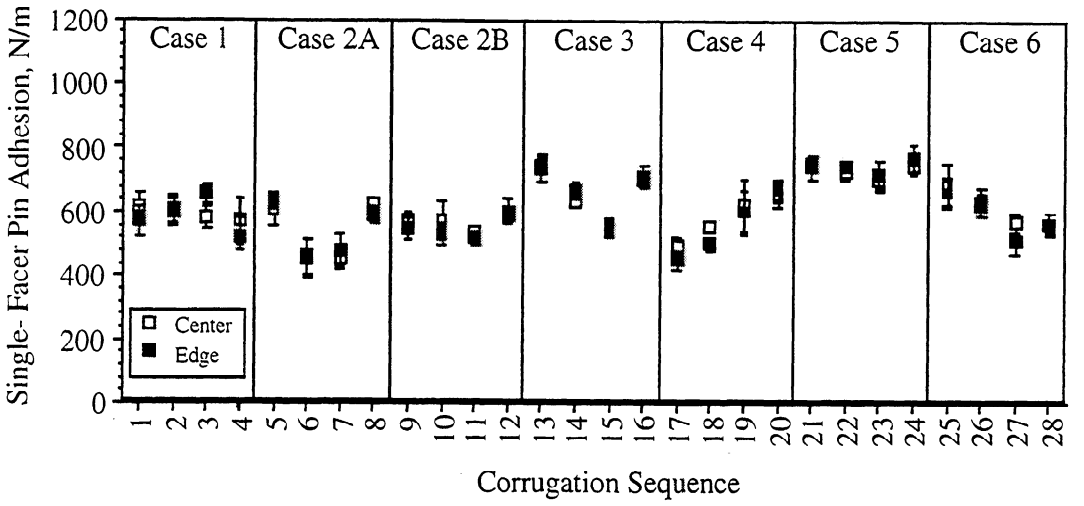

Figure C3. Single-Facer Pin Adhesion Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Sequence.

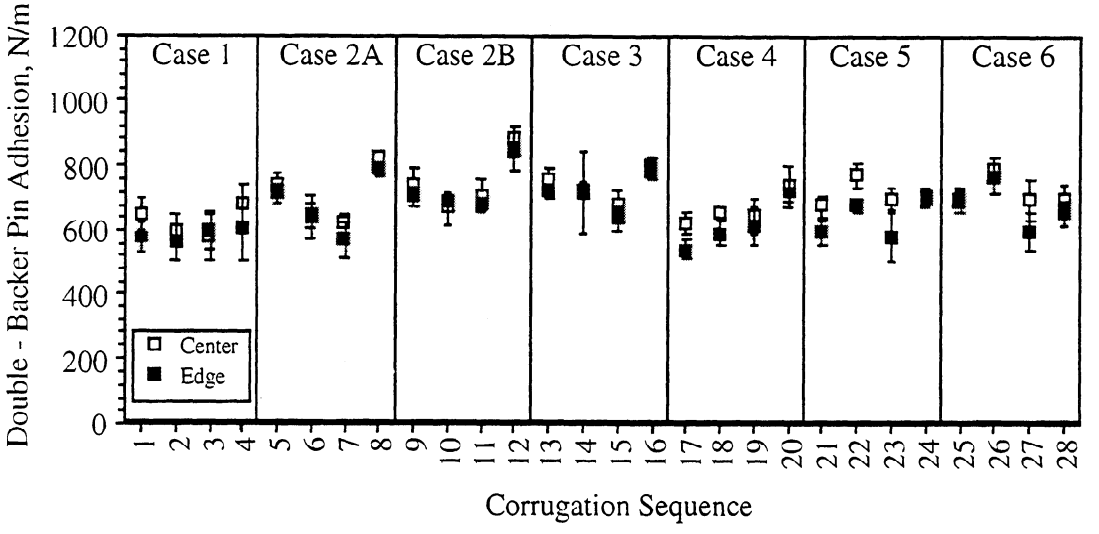

Figure C4. Double-Backer Pin Adhesion Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Sequence.

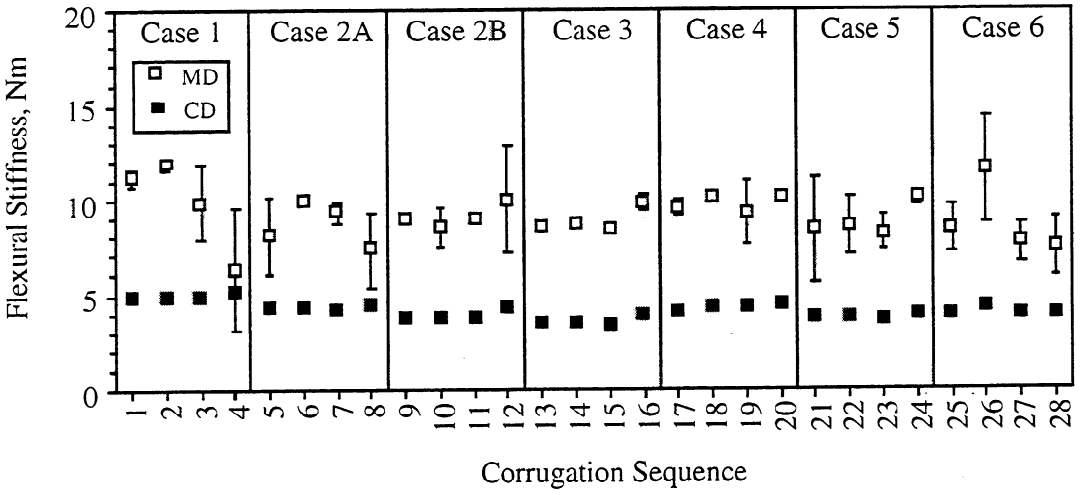

Figure C5. Flexural Stiffness Of Corrugated Board (As Measured In MD and CD Directions) Plotted Versus Corrugation Sequence.

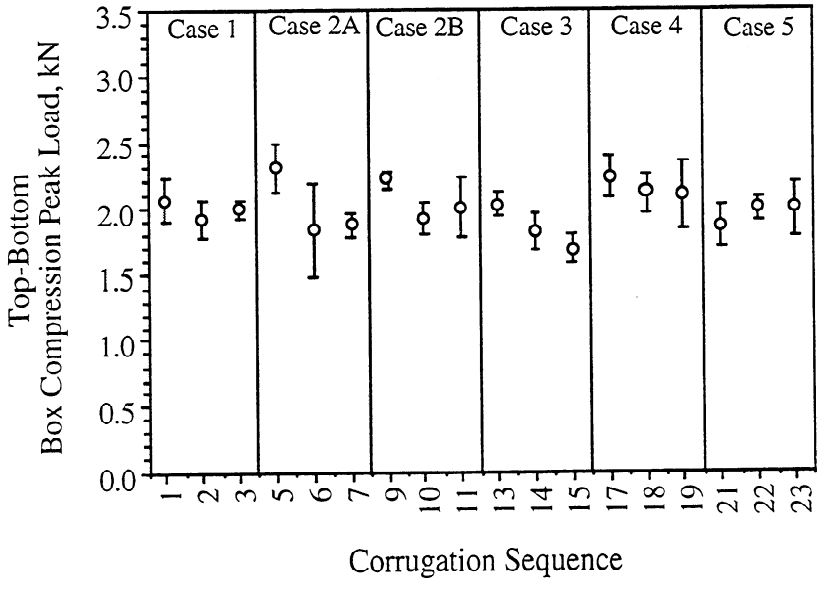

Figure C6. Top-To-Bottom Box Compression Peak Load Plotted Versus Corrugation Sequence.

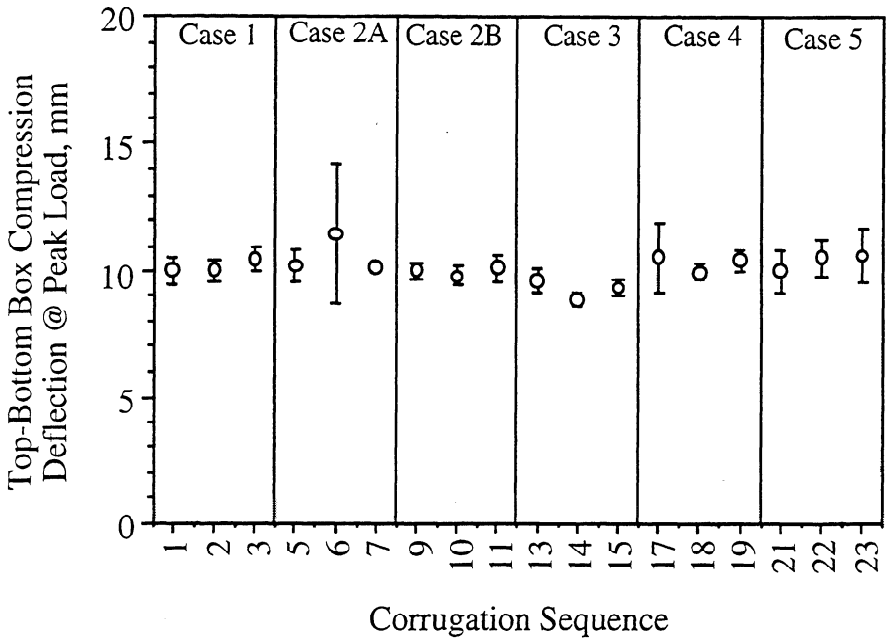

Figure C7. Top-To-Bottom Box Compression Deflection at Peak Load Plotted Versus Corrugation Sequence.

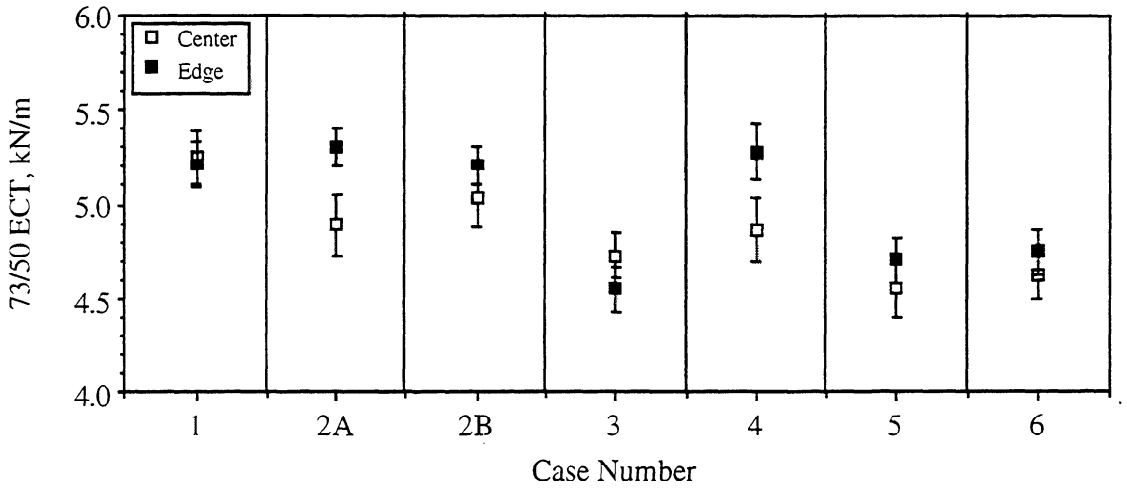

Figure C8. Edge Crush Test Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Case Number.

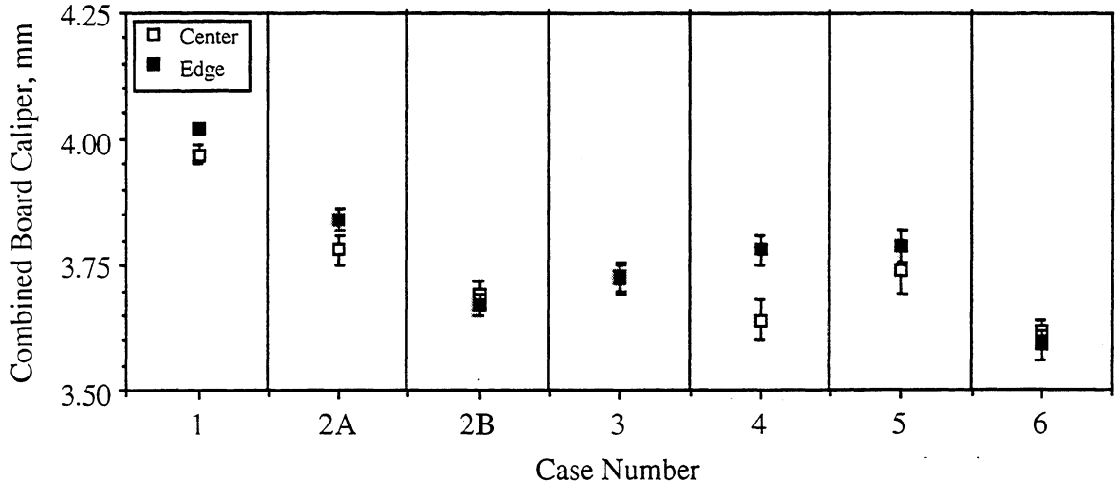

Figure C9. Caliper Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Case Number.

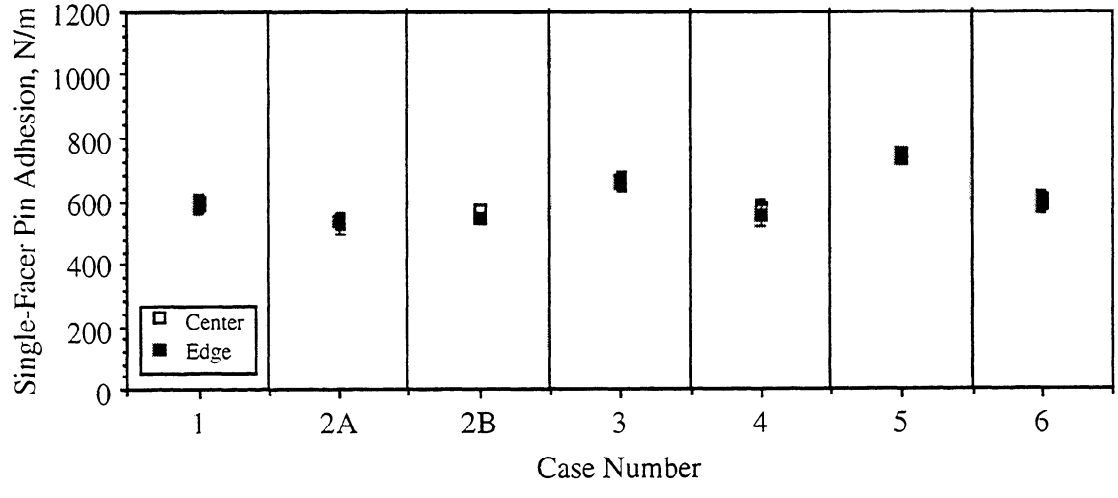

Figure C10. Single-Facer Pin Adhesion Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Case Number.

Figure C11. Double-Backer Pin Adhesion Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Case Number.

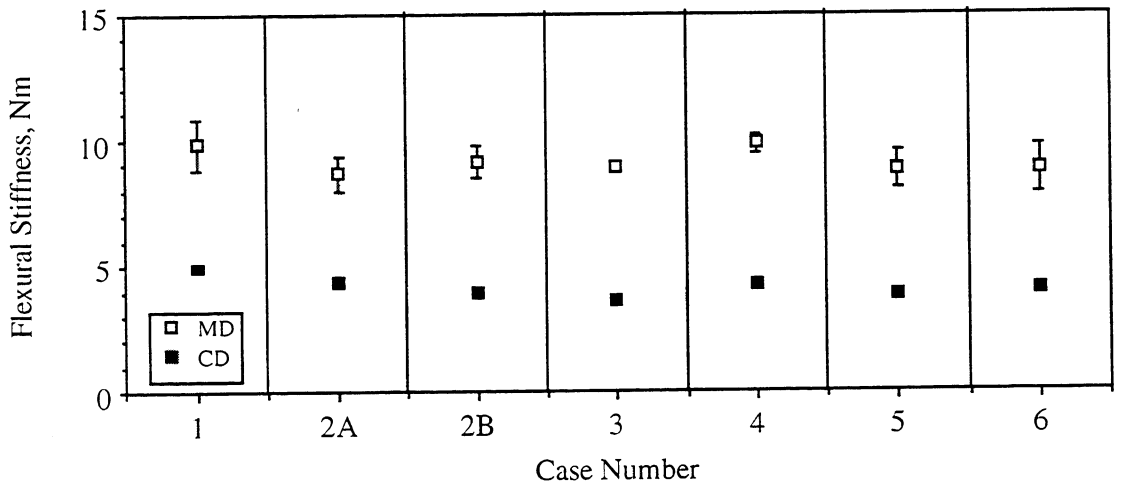

Figure C12. Flexural Stiffness Of Corrugated Board (As Measured In MD and CD Directions) Plotted Versus Corrugation Case Number.

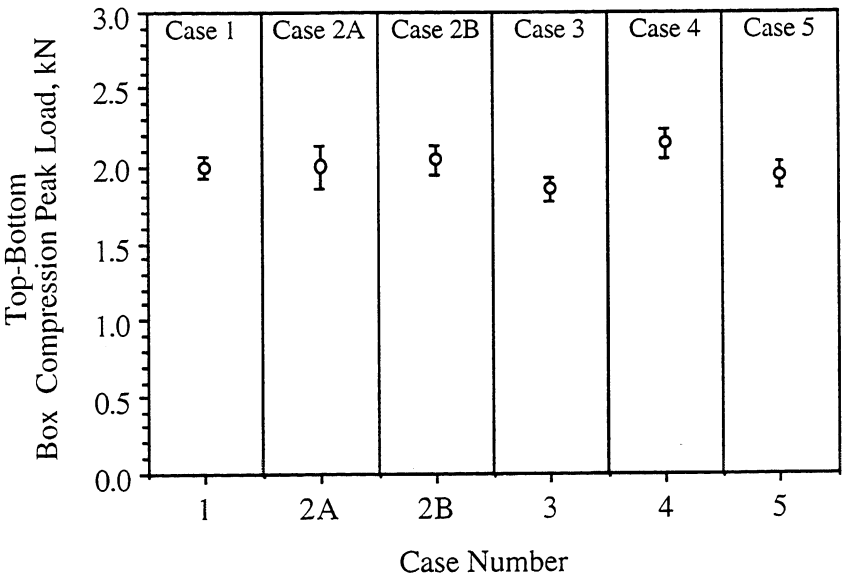

Figure C13. Top-To-Bottom Box Compression Peak Load Plotted Versus Corrugation Case Number.

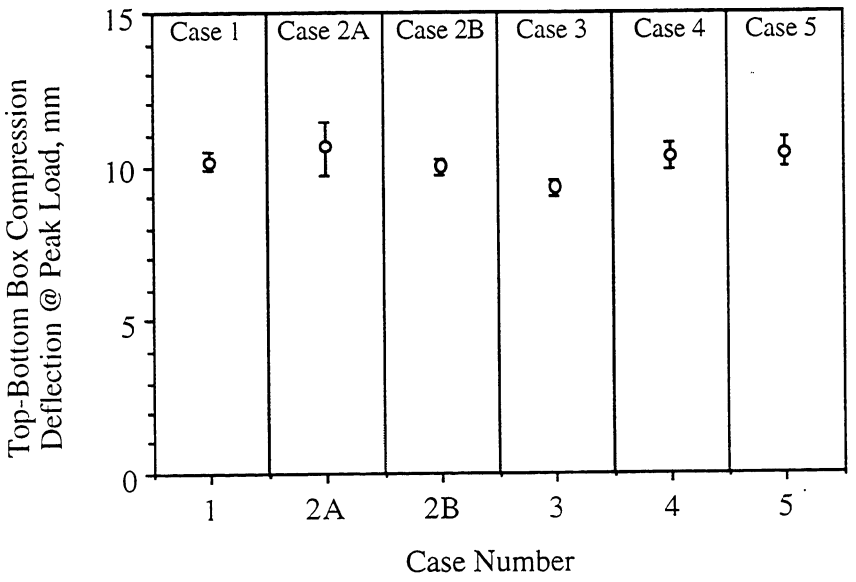

Figure C14. Top-To-Bottom Box Compression Deflection at Peak Load Plotted Versus

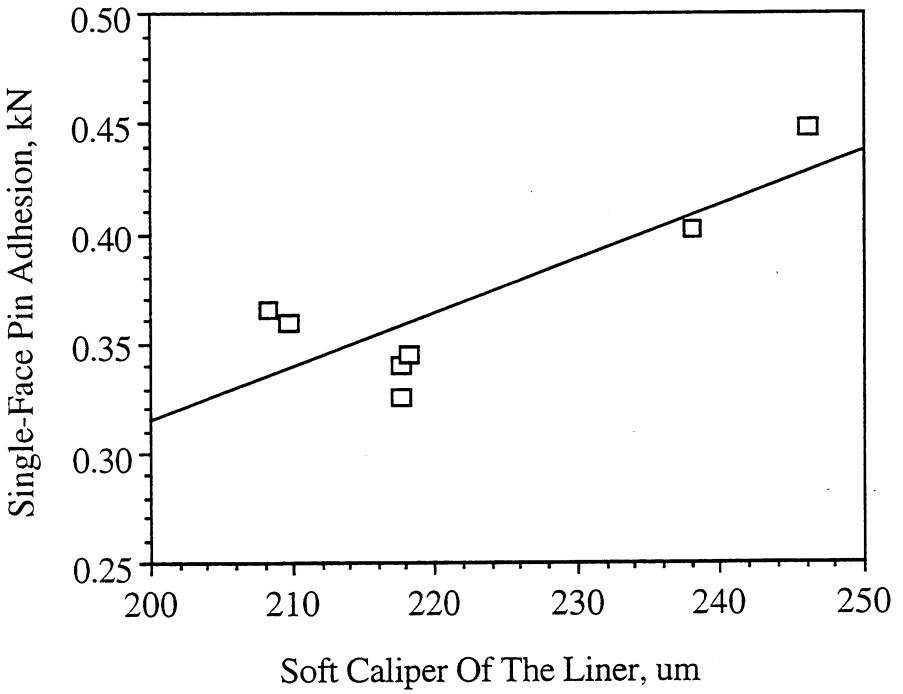

Figure C15. Single-Face Pin Adhesion Versus Linerboard Soft Caliper.

D. ECONOMICS

D1.) Summary

In September 1998 the Institute and Beloit Corporation were successful in producing 161 g/m^2 (33#) linerboard on a one-meter wide pilot paper machine. The demonstration included a comparison of impulse drying to single-felted wet pressing.

Test results show that impulse drying, when compared to single-felted wet pressing, yielded a 4 point increase in press dryness, and a 10% increase in CD STFI and CD ring crush.

Reels of wet pressed and impulse dried linerboard, produced on a pilot paper machine, were converted on a Stone Container commercial corrugator in October of 1998. Combined board and boxes made from the impulse dried linerboard were 10% stronger than board and boxes produced from the wet pressed linerboard.

Economic calculations demonstrate that impulse drying may be used to increase paper-machine productivity, on a tonnage basis, by about 17.2% for dryer limited machines. On

an area basis, basis weight reductions can be used to improve productivity by as much as 30% with substantial pulp cost savings.

D2.) Assumptions

It is assumed that an impulse dryer will be used to replace a third press on a paper machine that is currently dryer limited. It is further assumed that the installation of the impulse dryer will yield an improvement in press solids. The impulse dryer will also yield a strength improvement that will allow a basis weight reduction. The increased press dryness and basis weight reduction will allow the paper-machine speed to be increased until the machine is once again dryer limited.

For the wet pressing case, energy costs will include electric energy costs associated with pulp refining and steam costs associated with conventional drying. For the impulse drying case, the electric energy costs will include those for impulse dryer roll heating as well as pulp refining; steam costs for conventional drying will also be calculated.

As linerboard is sold on the basis of strength rather than by basis weight, the energy cost penalty of using impulse drying will be calculated on an area production basis. In a similar way, pulp cost savings will also be calculated on an area production basis.

D3. Calculations

Wet Pressing

Table D1 shows the input data for the conventional wet pressed case. In this example, the product at the reel is at **RS** = 95% solids and the width at the reel is **W** = 10 m. The linerboard that is produced has an o.d. basis weight of **OBWM** = 150 g/m^2 (**OBWF** = 30.7 lb/1000 ft^2). The basis weight at the reel is calculated from the reel solids and o.d. basis weight as **RBWM** = 158 g/m^2 (**RBWF** = 32.3 lb/1000 ft^2).

$$OBWF = 0.20482\ (OBWM) \quad \{1\}$$
$$RBWF = 100\ (OBWF)/(RS) \quad \{2\}$$
$$RBWM = 100\ (OBWM\ )/(RS) \quad \{3\}$$

The structure of the sheet influences the average freeness, which impacts needed refining energy. Hence, the freeness and percent of total weight of each of two plies are given. For the case shown, the top ply represents **%BW(1)** = 15% of the weight and is refined to **F(1)** = 669 ml CSF, while the bottom ply, representing the remaining **%BW(2)** = 85% of the weight, is refined to a freeness of F(2) = 669 ml CSF. The o.d. basis weight of each ply, **BW(i)**, is calculated from the weight percentages and the o.d. basis weight of the sheet.

$$BW(i) = (\%BW(i))(OBWF)/100 \quad \{4\}$$

The input and output conditions of the dryer section are given. In the example, solids into the dryer was **%Sin** = 47% and solids out of the dryer was **%Sout** = 95%. As an estimate, the mass of steam used in drying was assumed to be **R** = 1.5 times the mass of water that must be evaporated. The pressure of the steam in the conventional dryers was assumed to be **P** = 7.74 bar. Based on the steam tables, the latent heat of the steam was calculated as **Hfg** = 2051 kJ/kg.

$$Hfg = 2240.2 - 30.61\ P + 0.79767\ P^2 \quad \{5\}$$

At this point, the cost data for both the wet pressing and impulse drying cases are entered in Table 3-1. In the example, electricity costs **C1** = $0.03/kW-hr, pulp costs **C3** = $200/o.d. ton and steam costs **C2** = $0.01/kW-hr (**C2'** = $2.83/ million Btu).

$$C2' = 282.85\ (C2) \quad \{6\}$$

The paper-machine speed was also entered. For the example, the dryer limited machine speed was taken as **S** = 600 m/min.

In Table D2 the water evaporated by the dryer section was calculated as **We** = 161 g/m^2 (**WE** = 58,052 kg/hr).

$$We = [\ \{(1-(\%Sin/100))/(\%Sin/100)\}-\{(1-(\%Sout/100))/(\%Sout/100)\}\ ]\ (OBWM) \quad \{7\}$$

$$WE = 0.06\ We\ (S)\ (W) \quad \{8\}$$

The amount of steam used in the dryer section is calculated as **SU** = 87,077 kg/hr. Likewise, the steam energy is calculated as **SEU** = 178,601,144 kJ/hr. The steam energy per kg of product at the reel is calculated as **SEUR** = 0.873 kW-hr/kg.

$$SU = R\ (WE) \quad \{9\}$$

$$SEU = Hfg\ (SU) \quad \{10\}$$

$$SEUR = 0.0002778\ SEU/Pr \quad \{11\}$$

Where the amount of paper produced at the reel is **Pr** = 56,842 kg/hr, or on an area basis, **PR** = 360,000 m^2/hr.

$$Pr = 0.06\ S\ (W)(RBWM) \quad \{12\}$$

$$PR = 1000\ (Pr)/(RBWM) \quad \{13\}$$

Also shown in Table 3-2 are the pulp usage, **PU** = 0.0154 OD ton/1000 ft^2 and pulp costs, **CP** = $3.07 /1000 ft2, at the reel.

$$PU = 0.00010241\ (OBWM) \quad \{14\}$$

$$CP = PU\ (C3) \quad \{15\}$$

In order to calculate energy used in refining, the average freeness was first calculated as **Fave** = 669 ml CSF. The refining energy is then estimated as **Re** = 71 kW-hr/ton at the reel (**RER** = 0.079 kW-hr/kg at the reel) for the sample case.

$$Fave = [(\%BW(1)/100)\ (F(1))]+[(\%BW(2)/100)\ (F(2))] \quad \{16\}$$

$$Re = 390.77 - 0.47733\ (Fave) \quad \{17\}$$

$$RER = 0.0011023\ (Re) \quad \{18\}$$

The cost of energy may now be calculated. In particular, the total energy cost for the sample case was calculated as **CTEAF** = $0.16/ 1000 ft^2 of production at the reel.

$$CEL = RER\ (C1) \quad \{19\}$$

CST = SEUR (C2) {20}
CTE = CEL + CST {21}
CTET = 907.186 (CTE) {22}
CELA = CEL (RBWM)/1000 {23}
CSTA = CST (RBWM)/1000 {24}
CTEA = CELA + CSTA {25}
CTEAF = 92.905 (CTEA) {26}

Impulse Drying

The impulse drying case, as shown in Table D3, assumes that the product basis weight can be reduced by **%WR** = 10% without sacrificing product strength. The o.d. basis weight can then be calculated as **OBWMd** = 135 g/m^2 (**OBWFd** = 27.7 lb/1000 ft^2) and the basis weight at the reel as **RBWMd** = 142 g/m^2 (**RBWFd** = 29.1 lb/1000 ft^2).

OBWMd = [1- (%WR/100)] (OBWM) {27}
OBWFd = 0.20482 (OBWMd) {28}
RBWFd = 100 (OBWFd /RS) {29}
RBWMd = 100 (OBWMd /RS) {30}

Reflecting the increased refining of our pilot experiments, the freeness of each of the layers of the sample case are assumed to be **Fd (i)** = 613 ml CSF. Also, as in our pilot experiments, we have utilized an experimental correlation to predict press dryness of **%Sind** = 51%, resulting from the impulse dryer operating at a press roll temperature of **T** = 260°C.

$$\%Sind = 47.121 - 0.0086215\ T + 0.000087128\ T^2 \quad \{31\}$$

Given the press solids performance of the impulse dryer, the water that must be evaporated in the dryer section can be calculated for the sample case as, **Wed** = 124 g/m^2, see Table D4. Based on the water that can be evaporated by the "dryer-limited" dryer, and the reduction in basis weight of the product, the increased paper-machine speed may be calculated as **Sd** = 781 m/min.

Wed = [{(1-(%Sind/100))/(%Sind/100)}-{(1- (%Soutd/100))/(%Soutd/100)}] (OBWMd) {32}
Sd = 0.06 WE / (Wed) (W) {33}

Given production at the reel of **Prd** = 66,633 kg/hr (**PRd** = 468,900 m^2/hr), steam usage may be calculated as **SEURd** = 0.745 kW-hr/kg at the reel.

SEURd = 0.0002778 SEU / (Prd) {34}
Prd = 0.06 Sd (W) (RBWMd) {35}
PRd = 1000 Prd / (RBWMd) {36}

Pulp usage may then be calculated as **Pud** = 0.0138 o.d. ton/1000 ft^2 and the cost of that pulp may be calculated as **CPd** = $2.77/1000 ft^2.

Pud = 0.00010241 (OBWMd) {37}

$$CPd = Pud\ (C3) \quad \{38\}$$

To calculate refining energy, the average freeness was then calculated as **Faved** = 613 ml CSF. The refining energy may then be estimated as **Red** = 98 kW-hr/ton at the reel (**RERd** = 0.108 kW-hr/kg at the reel) for the sample case.

$$Faved = [(\%BWd(1)/100)\ (Fd(1))]+[(\%BWd(2)/100)\ (Fd(2))] \quad \{39\}$$

$$Red = 390.77 - 0.47733\ (Faved) \quad \{40\}$$

$$RERd = 0.0011023\ (Red) \quad \{41\}$$

Based on experimental roll heating measurements, the energy transferred by the impulse dryer, including losses, was **RETd** = 97 kJ/m^2 when the press roll was heated to **T** = 260 °C. The roll heating power usage may then be calculated as **RHPUd** = 12,606 kW-hr/hr. The roll heating power is then **RHPAd** = 0.0269 kW-hr/m^2 (**RHPMd** = 0.189 kW-hr/kg at the reel).

$$RETd = 0.19116\ (-92.257 + 2.3021\ T) \quad \{42\}$$

$$RHPUd = 0.000278\ RETd\ (PRd) \quad \{43\}$$

$$RHPAd = 0.000053\ (-92.257 + 2.3021\ T) \quad \{44\}$$

$$RHPMd = 1000\ RHPAd/(RBWMd) \quad \{45\}$$

The cost of energy may now be calculated. In particular the total energy cost for the sample case is calculated as **CTEAFd** = \$0.22/1000 ft^2 of production at the reel.

$$CELd = (RERd + RHPMd)\ (C1) \quad \{46\}$$

$$CSTd = SEURd\ (C2) \quad \{47\}$$

$$CTEd = CELd + CSTd \quad \{48\}$$

$$CTETd = 907.186\ (CTEd) \quad \{49\}$$

$$CELAd = CELd\ (RBWMd)/1000 \quad \{50\}$$

$$CSTAd = CSTd\ (RBWMd)/1000 \quad \{51\}$$

$$CTEAd = CELAd + CSTAd \quad \{52\}$$

$$CTEAFd = 92.905\ (CTEAd) \quad \{53\}$$

For simplicity, all of the input and output data are summarized on Table D5. Also shown at the bottom of Table d5 are the calculations of energy cost penalty of \$4.79/ton at the reel (\$0.05/1000 ft^2), productivity increase of 17.2% on a tonnage basis and 30.2% on a product area basis. Pulp cost savings for the sample case was \$0.31/1000 ft^2. Clearly, the benefit of saving pulp costs far outweighs slightly higher energy costs.

$$\text{Energy Cost Penalty (Tonnage)} = CTETd - CTET \quad \{54\}$$

$$\text{Energy Cost Penalty (Area)} = CTEAFd - CTEAF \quad \{55\}$$

$$\text{Productivity Increase (Tonnage)} = 100\ (Prd-Pr)/(Pr) \quad \{56\}$$

$$\text{Productivity Increase (Area)} = 100\ (PRd-PR)/(PR) \quad \{57\}$$

$$\text{Pulp Cost Savings (Area)} = CP-CPd \quad \{58\}$$

D4.) Discussion

The economic model described in the previous section was exercised to explore the impact of operating parameters (basis weight reduction, electric power cost, and pulp cost) on economic incentives of the technology. All of the other parameters of the model were set to those of the sample case reviewed in the previous section.

Figure D1 shows the impact of basis weight reduction and electric power costs on the energy penalty (on a tonnage basis) associated with using the technology. At a typical electric power cost of $0.03 to $0.04 per kW-hr, a cost penalty of between $5.00 and $7.00 per ton should be anticipated.

As linerboard is sold on strength properties and not basis weight, it is more relevant to explore the economics of the technology on the basis of cost per 1000 ft^2 of product produced. On that basis, Figure D2 shows that the energy cost penalty should range from $0.05 to $0.08 per 1000 ft^2 of production.

To put this energy cost penalty into perspective, we need to consider that reducing the basis weight will allow us to significantly increase productivity. This productivity increase is shown in Figure D3. It is observed that even without reducing the basis weight, impulse drying will result in a 17% increase in production. If we can reduce the basis weight by 10%, we can increase productivity by about 30%.

Our ability to reduce basis weight has a large impact on pulp costs. Figure D4 shows pulp cost savings as a function of pulp cost and the amount of basis weight reduction that we are able to achieve. Bracketing the pulp cost between $100 to $200 per ton and bracketing the basis weight reduction to between 7% and 10%, we should anticipate pulp costs savings of between $0.10 and $0.30 per 1000 ft^2.

Combining the energy cost penalty with the pulp cost savings, impulse drying will positively impact operating costs from $0.02 to $0.25 per 1000 ft^2 of production. For a machine producing 121millionft^2/day, operating cost savings of between $2,400 to $30,000/day could be realized.

D5.) Acknowledgements

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Table D1. Input Data: Conventional

Reel State: (1a)

Solids @ Reel **RS**, %	Width @ Reel **W**, m
95	**10**

Total Sheet: (1b)

o.d. Basis Wt. **OBWM**, g/m^2	o.d. Basis Wt., **OBWF**, lbm/1000ft^2	Reel Basis Wt., **RBWF**, lbm/1000ft^2	Reel Basis Wt., **RBWM**, g/m^2
150	30.7	32.3	158

Sheet Structure: (1c)

Ply Number **PLY(i)**	Freeness, **F(i)**, ml CSF	OD Basis Wt., **%BW(I)**, %	OD Basis Wt., **BW(i)**, lbm/1000ft^2
1	**669**	**15**	4.6
2	**669**	**85**	26.1

Drying Input Data: (1d)

Solids Into Dryer **%Sin**, %	Solids Out Of Dryer **%Sout**, %	Steam/Water Use Ratio **R**	Steam Pressure **P**, bar	Latent Heat Of Steam **Hfg**, kJ/kg
47	**95**	**1.5**	**7.74**	2051

Cost Input Data: (1e)

Electricity Cost **C1**, $/kW-hr	Steam Cost **C2**, $/kW-hr	Steam Cost **C2'**, $/million Btu	Pulp Cost **C3**, $/o.d.Ton
0.030	**0.01**	2.83	**200**

Dryer Limited PM Conditions: (1f)

Speed @ Reel **S**, m/min
600

Table D2. Calculations: Conventional

Water Evaporated by Dryer Section (2a)

Water Evaporated **We**, g/m^2	Water Evaporated **WE**, kg/hr
161	58052

Steam Used By Dryer Section: (2b)

Steam Used **SU**, kg/hr	Steam Energy Used **SEU**, kJ/hr	Steam Energy Used **SEUR**, kW-hr/kg @ Reel
87077	178601144	0.873

Paper Production Rate: (2c)

Paper Produced @ Reel **Pr**, kg/hr	Paper Produced @ Reel **PR**, m^2/hr	Pulp Usage **PU**, o.d.Ton/1000 ft^2	Pulp Cost **CP**, $/1000 ft^2
56842	360000	0.0154	3.07

Refining Energy: (2d)

Average Freeness **Fave**, ml CSF	Refining Energy Use **Re**, kW-hr/ton @ Reel	Refining Energy Use **RER**, kW-hr/kg @ Reel
669	71	0.079

Cost Of Energy: (2e)

Cost Of Electric Power **CEL**, $/kg @ Reel	Cost Of Steam **CST**, $/kg @ Reel	Total Energy Cost **CTE**, $/kg @ Reel	Total Energy Cost **CTET**, $/ton @ Reel
0.0024	0.0087	0.0111	10.06

Cost Of Energy: (2f)

Cost Of Electric Power **CELA**, $/m^2 @ Reel	Cost Of Steam **CSTA**, $/m^2 @ Reel	Total Energy Cost **CTEA**, $/m^2 @ Reel	Total Energy Cost **CTEAF**, $/1000 ft^2 @ Reel
0.00037	0.00138	0.0018	0.16

Variable Costs: (2g)

Variable Energy Costs **VECOST**, $/day	Variable Pulp Costs **VPCOST**, $/day	Total Variable Costs **TVCOST**, $/day
15,130	285,719	300,849

Table D3. Input Data: Impulse Drying

Reel State (3a) / (3b)

Solids @ Reel **RS**, %	Width @ Reel **W**, m	o.d. Wt. Reduction **%WR**, %
95	10	**10**

Total Sheet (3c)

o.d. Basis Wt. **OBWMd**, g/m^2	o.d. Basis Wt., **OBWFd**, lbm/1000 ft^2	Reel Basis Wt., **RBWFd**, lbm/1000 ft^2	Reel Basis Wt., **RBWMd**, g/m^2
135	27.7	29.1	142

Sheet Structure (3d)

Ply Number **PLY(i)**	Freeness, **Fd(i)**, ml CSF	o.d. Basis Wt., **%BWd(i)**, %	o.d. Basis Wt., **BWd(i)**, lbm/1000 ft^2
1	**613**	**15**	4.1
2	**613**	**85**	23.5

Drying Input Data (3e)

Solids Into Dryer **%Sind**, %	Solids Out Of Dryer **%Sout**, %	Steam/Water Use Ratio **R**	Steam Pressure **P**, bar	Latent Heat Of Steam **Hfg**, kJ/kg
51	95	1.5	7.74	2051

Cost Input Data (3f)

Electricity Cost **C1**, $/kW-hr	Steam Cost **C2**, $/kW-hr	Steam Cost **C2'**, $/million Btu	Pulp Cost **C3**, $/o.d. Ton
0.030	0.01	2.83	200

Impulse Drying Data (3g)

Roll Temperature **T**, °C
260

Table D4. Calculations: Impulse Drying

Water Evaporated By Dryer Section: (4a)	Water Evaporated **Wed**, g/m^2
	124

Speed @ Reel: **Table 4b**	Speed @ Reel **Sd**, m/min
	781

Steam Used By Dryer Section: (4c)	Steam Used **SU**, kg/hr	Steam Energy Used **SEU**, kJ/hr	Steam Energy Used **SEURd**, kW-hr/kg @ Reel
	87077	178601144	0.745

Paper Production Rate: (4d)	Paper Produced @ Reel **Prd**, kg/hr	Paper Produced @ Reel **PRd**, m^2/hr	Pulp Usage **Pud**, OD Ton/1000ft^2	Pulp Cost **CPd**, $/1000 ft^2
	66633	468900	0.0138	2.77

Refining Energy: (4e)	Average Freeness **Faved**, ml CSF	Refining Energy Use **Red**, kW-hr/Ton @ Reel	Refining Energy Use **RERd**, kW-hr/kg @ Reel
	613	98	0.108

I.D. Energy: (4f)	Roll Energy Transfer **RETd**, kJ/m^2	Roll Heating Power Use **RHPUd**, kW-hr/hr	Roll Heating Power **RHPAd**, kW-hr/m^2	Roll Heating Power **RHPMd**, kW-hr/kg @ Reel
	97	12606	0.0269	0.189

Cost Of Energy: (4g)	Cost Of Electric Power **CELd**, $/kg @ Reel	Cost Of Steam **CSTd**, $/ kg @ Reel	Total Energy Cost **CTEd**, $/ kg @ Reel	Total Energy Cost **CTETd**, $/ Ton @ Reel
	0.0089	0.0074	0.0164	14.85

Cost Of Energy: (4h)	Cost Of Electric Power **CELAd**, $/m^2 @ Reel	Cost Of Steam **CSTAd**, $/m^2 @ Reel	Total Energy Cost **CTEAd**, $/m^2 @ Reel	Total Energy Cost **CTEAFd**, $/1000 ft^2 @ Reel
	0.0013	0.0011	0.0023	0.22

Variable Costs: (4i)	Variable Energy Costs **VECOSTd**, $/day	Variable Pulp Costs **VPCOSTd**, $/day	Total Variable Costs **TVCOSTd**, $/day
	26,175	334,934	361,109

Table D5. Overview of Input and Output Data

Conventional Data	Input Data
Solids @ Reel, %	95
Width @ Reel, m	10
o.d. Basis Wt., gsm	150
Freeness layer 1, ml CSF	669
Freeness Layer 2, ml CSF	669
o.d. Wt Layer 1, %	15
o.d. Wt Layer 2, %	85
Solids Into Dryer, %	47
Solids Out Of Dryer, %	95
Steam/Water Ratio	1.5
Steam Press, bar	7.74
Electricity Cost, $/kW-hr	0.03
Steam Cost, $/kW-hr	0.01
Speed @ Reel, m/min	600

Impulse Drying Data	Input Data
Basis Wt. Reduction, %	10
Freeness layer 1, ml CSF	613
Freeness Layer 2, ml CSF	613
o.d. Wt Layer 1, %	15
o.d. Wt Layer 2, %	85
Roll Temperature, °C	260

Pulp Cost, $/o.d. Ton	200

Conventional	
Variable Energy Costs, $/day	15,130
Variable Pulp Costs, $/day	285,719
Total Variable Costs, $/day	300,849
Impulse Drying	
Variable Energy Costs, $/day	26,175
Variable Pulp Costs, $/day	334,934
Total Variable Costs, $/day	361,109

Conventional	Output Data
o.d. Basis Wt., lbm/1000 ft^2	30.7
Reel Basis Wt., lbm/1000 ft^2	32.3
Reel Basis Wt., gsm	158
o.d. Basis Wt. Layer 1, g/m^2	4.6
o.d. Basis Wt. Layer 2, g/m^2	26.1
Latent Heat of Steam, kJ/kg	2051
Steam Cost, $/MMBtu	2.83
Water Evaporated, g/m^2	161
Water Evaporated, kg/hr	58052
Steam Used, kg/hr	87077
Steam Energy Used, kJ/hr	178601144
Steam Energy Used, kW-hr/kg @ Reel	0.873
Paper Produced @ Reel, kg/hr	56842
Paper Produced @ Reel, m^2/hr	360000
Pulp Usage, o.d. Ton/1000 ft^2	0.0154
Pulp Cost, $/1000 ft^2	3.07
Average Freeness, ml CSF	669
Refining Energy Used, kW-hr/ton @ Reel	71
Refining Energy Used, kW-hr/kg @ Reel	0.079
Cost of Electric Power, $/kg @ Reel	0.0024
Cost of Steam, $/kg @ Reel	0.0087
Total Energy Cost, $/kg @ Reel	0.0111
Total Energy Cost, $/ton @ Reel	10.06
Cost of Electric Power, $/m^2 @ Reel	0.00037
Cost of Steam, $/m^2 @ Reel	0.00138
Total Energy Cost, $/m^2 @ Reel	0.00175
Total Energy Cost, $/1000 ft^2 @ Reel	0.163

I.D. Energy Cost Penalty, $/ton @ Reel	4.79
I.D. Energy Cost Penalty, $/1000 ft^2	0.05
I.D. Productivity Tonnage Increase, %	17.22
I.D. Productivity ft^2 Increase, %	30.25
I.D. Pulp Cost Savings, $/1000 ft^2	0.31

Impulse Drying	Output Data
Solids Into Dryer, %	50.8
o.d. Basis Wt., lbm/1000 ft^2	27.7
Reel Basis Wt., lbm/1000 ft^2	29.1
Reel Basis Wt., gsm	142
o.d. Basis Wt. Layer 1, g/m^2	4.1
o.d. Basis Wt. Layer 2, g/m^2	23.5
Latent Heat of Steam, kJ/kg	2051
Steam Cost, $/MMBtu	2.83
Water Evaporated, g/m^2	124
Speed @ Reel, m/min	781
Steam Used, kg/hr	87077
Steam Energy Used, kJ/hr	178601144
Steam Energy Used, kW-hr/kg @ Reel	0.745
Paper Produced @ Reel, kg/hr	66633
Paper Produced @ Reel, m^2/hr	468900
Pulp Usage, o.d. Ton/1000 ft^2	0.0138
Pulp Cost, $/1000 ft^2	2.77
Average Freeness, ml CSF	613
Refining Energy Used, kW-hr/ton @ Reel	98
Refining Energy Used, kW-hr/kg @ Reel	0.108
Roll Energy Transfer, kJ/m^2	96.8
Roll Heating Power Use, kW-hr/hr	12606
Roll Heating Power, kW-hr/m^2	0.0269
Roll Heating Power, kW-hr/kg @ Reel	0.189
Cost of Electric Power, $/kg @ Reel	0.0089
Cost of Steam, $/kg @ Reel	0.0074
Total Energy Cost, $/kg @ Reel	0.0164
Total Energy Cost, $/Ton @ Reel	14.85
Cost of Electric Power, $/m^2 @ Reel	0.0013
Cost of Steam, $/m^2 @ Reel	0.0011
Total Energy Cost, $/m^2 @ Reel	0.0023
Total Energy Cost, $/1000 ft^2 @ Reel	0.216

Percent Increase In Variable Costs, %	20.03

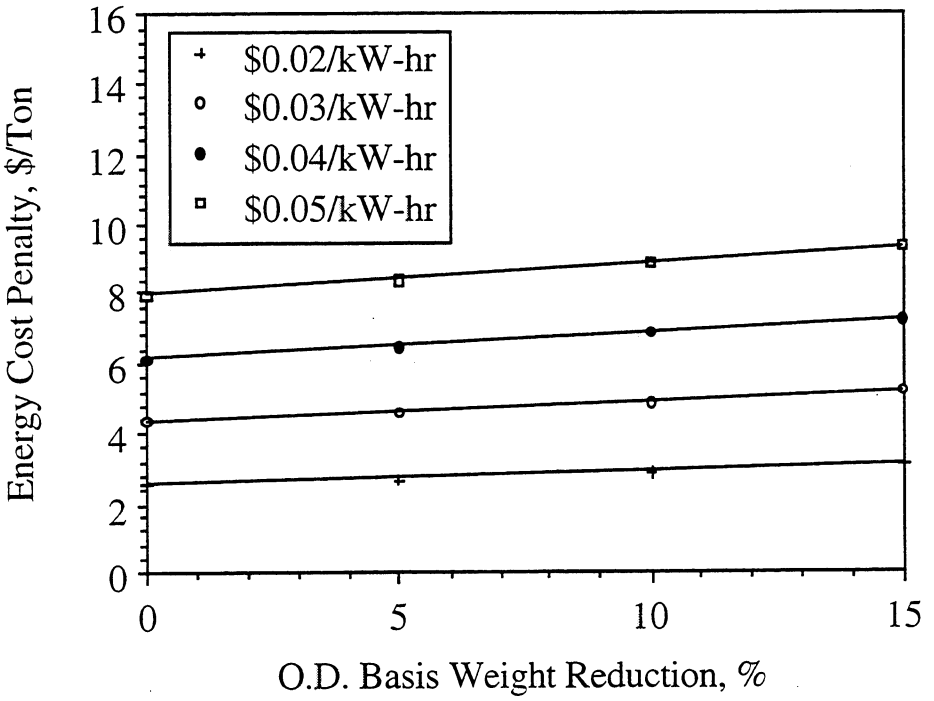

Figure D1. Energy Cost Penalty (Tonnage Basis)Versus O. D. Basis Weight Reduction.

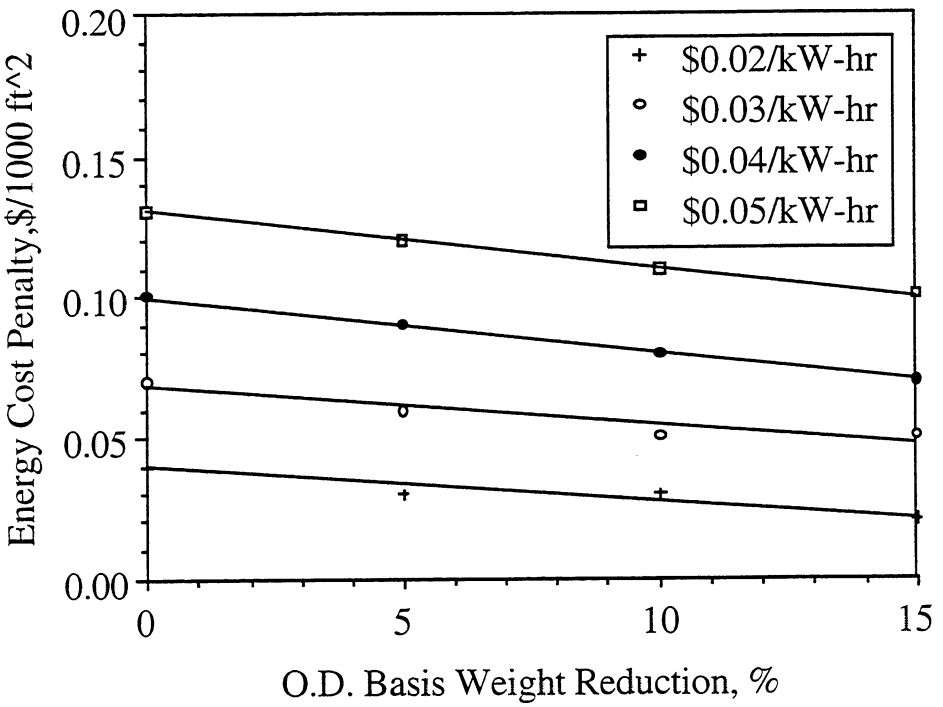

Figure D2. Energy Cost Penalty (Area Basis) Versus O.D. Basis Weight Reduction.

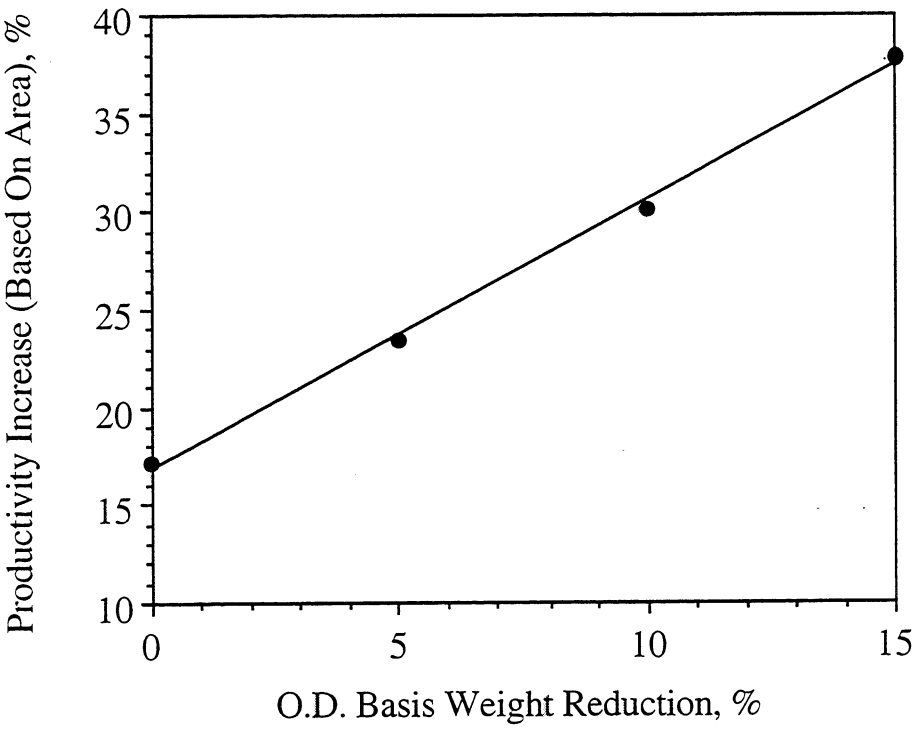

Figure D3. Productivity Increase (Area Basis) Versus O. D. Basis Weight Reduction.

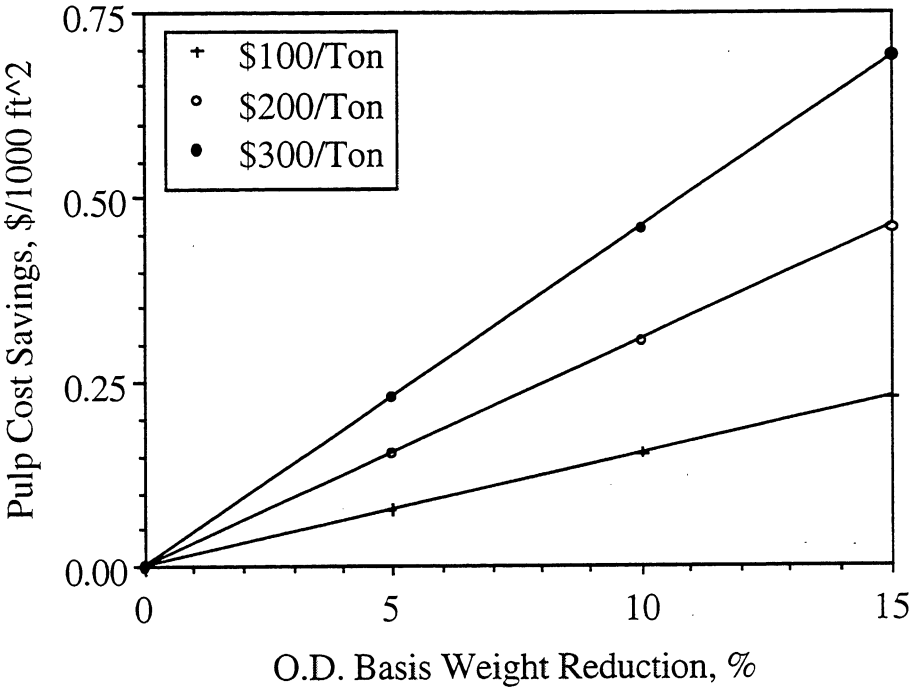

Figure D4. Pulp Cost Savings (Area Basis)Versus O. D. Basis Weight Reduction.

E. PAPER, BOARD AND BOX SAMPLING AND TESTING

E1.) Paper Sampling and Testing

The final reel width of the liner was about 0.79 m (31 in), which was trimmed to 0.76 m (30 in) and rewound. Before trimming, full width samples from the outside of each production rolls and at the marked positions of the test rolls were cut and divided between Beloit and IPST for testing. For detailed testing at IPST, the liner was divided into three 10-inch wide lanes in the cross direction, designated as Operator (front), Center, and Drive (back) lanes. Depending on the physical test, one to four repeat samples at different machine direction positions were tested to decrease the error bars.

Test Indexes (STFI, ring crush, tensile) were calculated individually using the OD basis weight of each test strip. The average basis weight for each sample was the average of all of the oven dried strip basis weights. The density was calculated from the average OD basis weight and average soft platen caliper for each sample.

E2.) Board and Box Sampling and Testing

Two sizes of blanks were produced. For the boxes about 750 blanks of each case 1.52 m (60 inches) long by 0.69 m (27 inches) wide were made. The die-cut blanks were slightly smaller, 1.02 m (40 inches) long by 0.71 m (28 inches) wide and about 250 were made for each case. Only die-cut blanks (about 750) were produced for Case 6 resulting in fewer total samples. About 250 Case 6 blanks were run through the flexo/folder/gluer operation for printing only.

Boxes and die cut samples were selected from each case in four sets of ten samples representing each quarter of the corrugator run. Of these, one set was die-cut samples and three sets were boxes. One specimen for each type of test was cut out of each box/panel resulting in ten test repeats for each set of samples. Of course the box compresion and glue joint tests were only done on three sets of samples for each case (no tests for Case 6 since there were no boxes made).

Table E1. Preliminary Data from Beloit Corporation.

	Sample ID (#)	Outgoing Solids (%)	Grammage (Conditioned) (g/m^2)	Basis Weight (Conditioned) (lb/1000 ft^2)	Apparent Density (Conditioned) (g/cm3)	Scott Bond (kJ/m2)	MD STFI Index (N*m/g)	CD STFI Index (N*m/g)	CD STFI (lbf/in)
Case 5	11942	46.91	162.2	33.23	0.571	0.153	29.10	15.70	14.54
Wet Press	11943	46.91	159.4	32.66	0.566	0.147	31.80	15.50	14.11
No Calender	11944	46.91	165.3	33.87	0.581	0.141	28.30	15.10	14.25
	11945	46.91	163.9	33.58	0.640	0.139	28.80	15.00	14.04
	Average	**46.91**	**162.7**	**33.34**	**0.590**	**0.145**	**29.50**	**15.33**	**14.24**
Case 3	11946	46.91	156.2	32.00	0.608	0.130	30.70	15.60	13.91
Wet Press	11947	46.91	160.9	32.97	0.603	0.141	31.00	16.50	15.16
35 KN/m Calender	11948	46.91	159.9	32.76	0.606	0.139	31.20	14.90	13.60
	11949	46.91	158.1	32.39	0.598	0.141	29.60	14.90	13.45
	Average	**46.91**	**158.8**	**32.53**	**0.604**	**0.138**	**30.63**	**15.48**	**14.03**
Case 2	11926	49.47	158.8	32.54	0.615	0.168	33.69	18.60	16.87
246 °C Roll Temp	11930	49.47	163.0	33.40	0.640	0.174	33.14	17.89	16.65
No Calender	11931	49.47	160.6	32.90	0.627	0.170	34.96	17.86	16.38
	11932	49.47	158.7	32.52	0.648	0.177	34.27	18.29	16.57
	Average	**49.47**	**160.3**	**32.84**	**0.633**	**0.172**	**34.02**	**18.16**	**16.62**
Case 6	11927	49.47	157.1	32.19	0.670	0.164	34.60	17.67	15.85
246 °C Roll Temp	11928	49.47	159.6	32.70	0.680	0.177	35.40	18.41	16.78
35 KN/m Calender	**Average**	**49.47**	**158.4**	**32.44**	**0.675**	**0.171**	**35.00**	**18.04**	**16.31**
Case 4	11933	50.47	156.1	31.98	0.611	0.183	35.31	16.42	14.64
260 °C Roll Temp	11934	50.47	160.1	32.80	0.616	0.177	33.49	17.60	16.09
No Calender	11935	50.47	161.3	33.05	0.638	0.177	34.78	17.81	16.40
	11936	50.47	160.9	32.97	0.624	0.164	31.68	16.62	15.27
	Average	**50.47**	**159.6**	**32.70**	**0.622**	**0.175**	**33.82**	**17.11**	**15.60**
204 °C Roll Temp	11950	49.08	162.3	33.25	0.634	0.153	31.81	16.73	15.50
218 °C Roll Temp	11951	49.35	159.8	32.74	0.634	0.156	33.12	16.94	15.46
232 °C Roll Temp	11952	49.79	159.5	32.68	0.626	0.153	32.13	17.54	15.97
246 °C Roll Temp	11953	50.38	161.2	33.03	0.627	0.160	30.28	17.86	16.44
260 °C Roll Temp	11954	51.06	164.1	33.62	0.640	0.149	32.75	16.63	15.58
274 °C Roll Temp	11955	51.06	164.1	33.62	0.640	0.149	32.75	16.63	15.58
288 °C Roll Temp	11956	52.05	162.7	33.34	0.630	0.162	30.05	15.73	14.61
WP - 43.8 KN/m Cal.	11937		162.7	33.34	0.637	0.145	30.1	16.0	14.87
WP - 37.1 KN/m Cal.	11938		161.4	33.07	0.628	0.143	29.5	17.2	15.85
WP - 10.5 KN/m Cal.	11939		161.5	33.09	0.588	0.145	30.8	16.3	15.03
WP - 28.7 KN/m Cal.	11940		159.6	32.70	0.585	0.143	31.3	15.9	14.49
WP - 19.8 KN/m Cal.	11941		158.0	32.37	0.570	0.147	31.6	16.1	14.53

Table E1 cont. Preliminary Data from Beloit Corporation.

	Sample ID (#)	FS Bendtsen Smoothness (ml/min)	WS Bendtsen Smoothness (ml/min)	FS Sheffield Smoothness (SU)	WS Sheffield Smoothness (SU)	Gurley Porosity (s/100 ml)	Bendtsen Permeability (ml/min)	MD Ring Crush Index (N m/g)	CD Ring Crush Index (N m/g)
Case 5	11942	2000	1985	>386	>386	9.8	1210	11.9	9.4
Wet Press	11943	1935	1985	>386	>386	9.9	1210	11.9	8.6
No Calender	11944	2020	2060	>386	>386	10.3	1175	12.0	8.6
	11945	650	695	365	364	14.0	860	11.9	7.4
	Average	**1985**	**2010**			**11.0**	**1114**	**11.9**	**8.5**
Case 3	11946	1370	1245	>383	>380	10.2	1175	11.7	8.4
Wet Press	11947	1410	1380	>378	377	9.8	1180	11.7	8.3
35 KN/m Calender	11948	1400	1420	>385	>382	10.3	1185	10.2	6.8
	11949	1290	1345	>385	>386	9.9	1185	11.4	8.9
	Average	**1393**	**1348**			**10.1**	**1181**	**11.3**	**8.1**
Case 2	11926	1650	2090	384	>386	24.5		12.7	9.0
246 °C Roll Temp	11930	1500	2240	>386	>386	24.9		14.1	9.0
No Calender	11931	1380	2130	>386	>386	26.2		13.7	9.0
	11932	1500	1920	>386	>386	25.9		13.5	9.1
	Average	**1510**	**2153**			**25.4**		**13.5**	**9.0**
Case 6	11927	1110	1370	322	385	26.4		11.5	9.5
246 °C Roll Temp	11928	910	1450	331	380	26.6		13.4	7.5
35 KN/m Calender	**Average**	**1010**	**1410**	**326.5**	**382.5**	**26.5**		**12.5**	**8.5**
Case 4	11933	1330	2180	>386	>386	24.7		12.8	10.3
260 °C Roll Temp	11934	1430	1830	>386	>386	23.8		12.2	8.8
No Calender	11935	1270	2290	>386	>386	24.2		14.0	10.1
	11936	1320	2110	>386	>386	25.5		13.1	9.5
	Average	**1343**	**2100**			**24.6**		**13.0**	**9.7**
204 °C Roll Temp	11950	1685	2020	>386	>386	16.4	745	11.3	8.1
218 °C Roll Temp	11951	1690	2060	>386	>386	17.3	715	12.4	10.4
232 °C Roll Temp	11952	1525	2095	>386	>386	19.1	615	12.8	8.0
246 °C Roll Temp	11953	1340	2055	>386	>386	18.3	640	12.7	9.1
260 °C Roll Temp	11954	1560	2110	>386	>386	17.1	655	11.7	9.3
274 °C Roll Temp	11955	1560	2110	>386	>386	17.1	690	11.1	8.7
288 °C Roll Temp	11956	1530	2165	>386	>386	19.0	635	11.7	7.3
WP - 43.8 KN/m Cal.	11937	1160	1150	362	370	12.7	955	11.1	7.5
WP - 37.1 KN/m Cal.	11938	1265	1355	372	>383	12.2	1025	11.3	8.4
WP - 10.5 KN/m Cal.	11939	1805	1840	>386	>386	10.7	1140	12.4	9.2
WP - 28.7 KN/m Cal.	11940	1900	1810	>386	>386	10.9	1105	13.3	10.0
WP - 19.8 KN/m Cal.	11941	1925	1850	>386	>386	10.8	1135	12.1	8.3

Table E1 cont. Preliminary Data from Beloit Corporation.

	Sample ID (#)	Burst Index (kPa m^2/g)	MD Tensile Index (N m/g)	CD Tensile Index (N m/g)	Tensile Ratio
Case 5	11942	2.59	66.65	24.08	2.77
Wet Press	11943	2.32	66.00	23.78	2.77
No Calender	11944	3.10	67.22	25.08	2.68
	11945	2.82	67.67	25.50	2.65
	Average	**2.71**	**66.89**	**24.61**	**2.72**
Case 3	11946	2.47	68.45	24.11	2.84
Wet Press	11947	2.89	70.10	24.98	2.81
35 KN/m Calender	11948	2.48	67.20	23.94	2.81
	11949	2.49	64.65	24.31	2.66
	Average	**2.58**	**67.60**	**24.34**	**2.78**
Case 2	11926	3.17	79.72	28.23	2.82
246 °C Roll Temp	11930	3.03	77.56	26.78	2.90
No Calender	11931	2.85	78.94	27.10	2.91
	11932	3.35	79.01	27.47	2.88
	Average	**3.10**	**78.81**	**27.40**	**2.88**
Case 6	11927	3.25	77.85	28.50	2.73
246 °C Roll Temp	11928	3.02	79.48	28.27	2.81
35 KN/m Calender	**Average**	**3.14**	**78.67**	**28.39**	**2.77**
Case 4	11933	3.05	81.08	29.32	2.77
260 °C Roll Temp	11934	2.89	77.44	26.78	2.89
No Calender	11935	3.18	80.26	27.71	2.90
	11936	2.91	78.06	27.15	2.88
	Average	**3.01**	**79.21**	**27.74**	**2.86**
204 °C Roll Temp	11950	2.72	72.20	26.50	2.72
218 °C Roll Temp	11951	2.70	74.60	27.44	2.70
232 °C Roll Temp	11952	2.90	69.18	26.41	2.62
246 °C Roll Temp	11953	2.84	72.91	25.08	2.91
260 °C Roll Temp	11954	3.14	74.38	26.93	2.76
274 °C Roll Temp	11955	2.82	72.57	26.34	2.75
288 °C Roll Temp	11956	2.80	77.23	25.78	3.00
WP - 43.8 KN/m Cal.	11937	2.53	68.18	24.76	2.75
WP - 37.1 KN/m Cal.	11938	2.86	70.82	24.34	2.91
WP - 10.5 KN/m Cal.	11939	2.60	68.29	25.42	2.69
WP - 28.7 KN/m Cal.	11940	2.34	69.08	25.11	2.75
WP - 19.8 KN/m Cal.	11941	3.11	72.21	25.26	2.86

Table E2. Average Physical Property Data.

Test Method		IPST			IPST	IPST				T460		UM535			
	Sample ID (#)	ZD-Long. SEM (MN m/kg)	95% C.I.	CV SEM (%)	Polar Angle (deg)	Soft Caliper (microns)	95% C.I.	Soft Caliper (mills)	95% C.I.	Gurley Porosity (s/100ml)	95% C.I.	FS Bendtsen Roughness (ml/min)	95% C.I.	WS Bendtsen Roughness (ml/min)	95% C.I.
Case 5	11942	0.1012	0.0019	10.5	0.69	243.9	2.2	9.6	0.1	9.25	0.14	2306	41	2364	50
Wet Press	11943	0.0972	0.0018	9.1		239.5	2.3	9.4	0.1	9.27	0.20	2322	42	2182	47
No Calender	11944	0.0951	0.0020	10.5		247.8	2.5	9.8	0.1	9.17	0.21	2280	39	2296	58
	11945	0.0991	0.0025	10.6		253.8	2.9	10.0	0.1	9.14	0.18	2331	52	2376	65
	Average	**0.0981**	**0.0010**	**10.2**	**0.69**	**246.2**	**1.3**	**9.7**	**0.0**	**9.21**	**0.09**	**2310**	**22**	**2305**	**28**
Case 3	11946	0.0784	0.0012	7.5		236.8	1.6	9.3	0.1	10.44	0.26	1514	42	1463	39
Wet Press	11947	0.0834	0.0018	8.1	1.48	236.4	1.5	9.3	0.1	8.83	0.15	1753	48	1672	40
35 KN/m Calender	11948	0.0821	0.0014	7.6	-2.45	239.3	1.7	9.4	0.1	9.63	0.18	1627	36	1625	36
	11949	0.0812	0.0013	7.8	0.97	239.7	1.7	9.4	0.1	9.55	0.20	1654	36	1630	36
	Average	**0.0813**	**0.0007**	**7.7**	**0.00**	**238.0**	**0.8**	**9.4**	**0.0**	**9.61**	**0.10**	**1637**	**20**	**1598**	**19**
Case 2	11926	0.1330	0.0027	8.4	1.20	220.1	3.2	8.7	0.1	23.23	0.43	1880	67	2303	59
246 °C	11930	0.1386	0.0026	8.8		217.9	2.8	8.6	0.1	22.40	0.36	1824	75	2452	60
No Calender	11931	0.1378	0.0024	8.7		214.7	5.0	8.5	0.2	23.59	0.49	1877	70	2256	57
	11932	0.1359	0.0027	9.2		217.9	3.9	8.6	0.2	22.96	0.41	1901	55	2211	56
	Average	**0.1363**	**0.0013**	**8.8**	**1.20**	**217.6**	**1.9**	**8.6**	**0.1**	**23.04**	**0.21**	**1870**	**34**	**2305**	**29**
Case 6	11927	0.1151	0.0028	9.7	1.21	206.2	1.3	8.1	0.1	24.40	0.54	1308	73	1777	54
246 °C	11928	0.1216	0.0036	9.9		210.5	1.7	8.3	0.1	25.45	0.57	1259	59	1734	44
35 KN/m Calender	**Average**	**0.1184**	**0.0023**	**9.8**	**1.21**	**208.3**	**1.1**	**8.2**	**0.0**	**24.93**	**0.39**	**1284**	**47**	**1756**	**35**
Case 4	11933	0.1350	0.0028	9.8	1.26	215.5	3.1	8.5	0.1	22.09	0.43	1910	72	2110	54
260 °C	11934	0.1343	0.0026	9.3		224.0	3.0	8.8	0.1	22.11	0.41	1920	71	2250	57
No Calender	11935	0.1344	0.0023	9.0		220.7	2.5	8.7	0.1	22.80	0.64	1890	64	2297	55
	11936	0.1379	0.0025	7.8		212.1	2.4	8.3	0.1	22.30	0.42	1859	68	2236	58
	Average	**0.1354**	**0.0013**	**9.0**	**1.26**	**218.1**	**1.4**	**8.6**	**0.1**	**22.32**	**0.24**	**1895**	**34**	**2223**	**28**
Case 1	225111	0.1228	0.0031	10.9	2.10	208.8	2.1	8.2	0.1	15.59	0.37	2039	99	2079	127
Commercial	225121	0.1090	0.0032	14.1	-3.99	210.9	2.6	8.3	0.1	16.76	0.49	2279	137	2131	123
Liner - Control	**Average**	**0.1159**	**0.0022**	**12.5**	**-0.94**	**209.8**	**1.7**	**8.3**	**0.1**	**16.17**	**0.31**	**2159**	**85**	**2105**	**88**
Commercial	107811	0.1391	0.0015	5.9		189.3	1.9	7.5	0.1	10.76	0.31	2792	58	2589	71
Medium	107812	0.1344	0.0019	7.5		182.3	1.8	7.2	0.1	11.29	0.32	2608	68	2831	68
	107813	0.1490	0.0018	6.5	-1.87	180.2	1.8	7.1	0.1	11.57	0.30	3036	51	2790	57
	107814	0.1390	0.0018	7.0		189.8	1.9	7.5	0.1	10.70	0.31	2912	43	2684	74
	107816	0.1490	0.0019	6.8		185.1	1.7	7.3	0.1	11.84	0.28	2797	73	2904	65
	Average	**0.1421**	**0.0008**	**6.7**	**-1.87**	**185.3**	**0.8**	**7.3**	**0.0**	**11.23**	**0.14**	**2829**	**27**	**2760**	**30**

Table E2 cont. Average Physical Property Data.

Test Method		IPST			IPST	IPST				T460		UM535			
	Sample ID (#)	ZD-Long. SEM (MN m/kg)	95% C.I.	CV SEM (%)	Polar Angle (deg)	Soft Caliper (microns)	95% C.I.	Soft Caliper (mills)	95% C.I.	Gurley Porosity (s/100ml)	95% C.I.	FS Bendtsen Roughness (ml/min)	95% C.I.	WS Bendtsen Roughness (ml/min)	95% C.I.
204 °C Roll Temp	11950	0.1133	0.0019	10.4	1.19	230.2	2.7	9.06	0.11	15.42	0.30	1838	62	2317	57
218 °C Roll Temp	11951	0.1201	0.0021	9.2		220.6	2.4	8.69	0.09	15.23	0.16	1880	67	2320	58
232 °C Roll Temp	11952	0.1255	0.0020	9.5		215.3	2.3	8.47	0.09	16.71	0.28	1806	52	2383	52
246 °C Roll Temp	11953	0.1252	0.0019	9.4		218.1	2.6	8.59	0.10	18.23	0.36	1749	60	2334	54
260 °C Roll Temp	11954	0.1291	0.0020	10.1		221.2	2.4	8.72	0.10	17.86	0.35	1852	61	2323	50
274 °C Roll Temp	11955	0.1162	0.0024	9.1		233.1	3.5	9.18	0.14	16.06	0.37	1912	74	2327	62
288 °C Roll Temp	11956	0.1221	0.0027	10.4		225.9	3.5	8.89	0.14	17.89	0.43	1910	78	2255	56
WP - 43.8 KN/m Cal.	11937											1379	87	1457	101
WP - 37.1 KN/m Cal.	11938											1595	94	1636	82
WP - 10.5 KN/m Cal.	11939											2092	126	2048	148
WP - 28.7 KN/m Cal.	11940											2082	169	2003	155
WP - 19.8 KN/m Cal.	11941											2271	107	2010	109

Table E2 cont. Average Physical Property Data.

Test Method		T538								IPST			
	Sample ID (#)	FS Sheffield Roughness (SU)	95% C.I.	WS Sheffield Roughness (SU)	95% C.I.	FS Sheffield Roughness (ml/min)	95% C.I.	WS Sheffield Roughness (ml/min)	95% C.I.	CD FS Emveco Micro Dev.	CD 95% C.I.	CD FS Emveco Micro Ave.	CD 95% C.I.
Case 5	11942	416	3	412	2	3482	23	3451	20	183.24	4.28	0.3396	0.0032
Wet Press	11943	415	3	412	3	3471	23	3446	26	183.48	4.96	0.3390	0.0049
No Calender	11944	414	3	414	3	3468	23	3462	28	185.57	4.79	0.3414	0.0044
	11945	416	3	414	3	3479	21	3462	25	182.91	6.48	0.3384	0.0059
	Average	**415**	**1**	**413**	**1**	**3475**	**11**	**3455**	**12**	**183.80**	**2.60**	**0.3396**	**0.0023**
Case 3	11946	374	3	370	3	3129	26	3096	24	107.64	5.49	0.2582	0.0069
Wet Press	11947	399	3	392	3	3342	22	3284	29	141.72	4.61	0.2971	0.0054
35 KN/m Calender	11948	385	3	383	2	3224	24	3206	19	122.32	3.97	0.2755	0.0044
	11949	387	3	385	2	3236	22	3218	18	120.04	4.65	0.2735	0.0058
	Average	**386**	**1**	**382**	**1**	**3233**	**12**	**3201**	**11**	**122.93**	**2.36**	**0.2761**	**0.0028**
Case 2	11926	403	4	420	3	3373	32	3512	24	83.92	3.34	0.2293	0.0042
246 °C	11930	391	4	417	2	3273	30	3493	20	88.63	5.59	0.2332	0.0051
No Calender	11931	399	4	417	3	3340	30	3490	26	83.24	3.18	0.2288	0.0042
	11932	400	3	408	3	3351	29	3415	25	84.48	3.43	0.2293	0.0045
	Average	**398**	**2**	**416**	**1**	**3334**	**15**	**3478**	**12**	**85.07**	**2.00**	**0.2301**	**0.0023**
Case 6	11927	364	7	387	5	3044	55	3239	43	68.82	2.68	0.2066	0.0046
246 °C	11928	361	6	387	4	3025	54	3237	34	70.06	1.83	0.2078	0.0029
35 KN/m Calender	**Average**	**363**	**5**	**387**	**3**	**3035**	**38**	**3238**	**28**	**69.44**	**1.63**	**0.2072**	**0.0027**
Case 4	11933	397	4	408	3	3326	32	3412	28	79.89	3.14	0.2232	0.0045
260 °C	11934	399	4	412	3	3337	37	3446	28	82.40	3.52	0.2260	0.0044
No Calender	11935	401	4	412	3	3359	34	3451	27	81.85	2.19	0.2260	0.0028
	11936	399	4	412	3	3342	37	3446	25	80.92	2.79	0.2250	0.0037
	Average	**399**	**2**	**411**	**2**	**3341**	**17**	**3439**	**14**	**81.26**	**1.48**	**0.2250**	**0.0019**
Case 1	225111	393	4	392	4	3288	36	3280	37	158.72	7.65	0.3105	0.0075
Commercial	225121	394	5	395	4	3295	40	3309	33	209.30	27.11	0.3343	0.0142
Liner - Control	**Average**	**393**	**3**	**394**	**3**	**3292**	**27**	**3294**	**25**	**184.01**	**14.09**	**0.3224**	**0.0080**
Commercial	107811												
Medium	107812												
	107813												
	107814												
	107816												
	Average												

Table E2 cont. Average Physical Property Data.

Test Method		T538								IPST			
	Sample ID (#)	FS Sheffield Roughness (SU)	95% C.I.	WS Sheffield Roughness (SU)	95% C.I.	FS Sheffield Roughness (ml/min)	95% C.I.	WS Sheffield Roughness (ml/min)	95% C.I.	CD FS Emveco Micro Dev.	CD 95% C.I.	CD FS Emveco Micro Ave.	CD 95% C.I.
204 °C Roll Temp	11950	396	4	416	4	3317	30	3479	30	88.47	2.37	0.2354	0.0031
218 °C Roll Temp	11951	397	5	410	3	3326	42	3429	24	82.76	3.34	0.2263	0.0045
232 °C Roll Temp	11952	395	4	415	3	3306	33	3471	26	78.74	1.72	0.2215	0.0026
246 °C Roll Temp	11953	401	4	424	3	3359	35	3551	21	79.41	1.72	0.2223	0.0025
260 °C Roll Temp	11954	402	4	420	3	3365	34	3515	27	73.20	1.42	0.2131	0.0022
274 °C Roll Temp	11955	401	5	421	3	3354	43	3526	29	74.57	2.06	0.2154	0.0030
288 °C Roll Temp	11956	402	5	420	4	3362	42	3518	31	78.02	3.62	0.2207	0.0048
WP - 43.8 KN/m Cal.	11937												
WP - 37.1 KN/m Cal.	11938												
WP - 10.5 KN/m Cal.	11939												
WP - 28.7 KN/m Cal.	11940												
WP - 19.8 KN/m Cal.	11941												

Table E2 cont. Average Physical Property Data.

Test Method						T527 (Diffuse)							
	Sample ID (#)	MD FS Emveco Micro Dev.	MD 95% C.I.	MD FS Emveco Micro Ave.	MD 95% C.I.	As Made Color Brightness	95% C.I.	L* Lightness	95% C.I.	a* +Redness -Greeness	95% C.I.	b* +Yellowness -Blueness	95% C.I.
Case 5	11942	142.22	8.50	0.2980	0.0073	15.59	0.08	59.35	0.16	5.63	0.60	24.14	0.09
Wet Press	11943	137.69	5.64	0.2912	0.0062	15.68	0.05	59.39	0.18	5.80	0.12	24.19	0.04
No Calender	11944	131.94	6.18	0.2860	0.0063	15.70	0.05	59.41	0.13	5.81	0.03	24.06	0.04
	11945	138.97	8.27	0.2925	0.0076	15.67	0.07	59.37	0.20	5.79	0.12	24.02	0.29
	Average	**137.70**	**3.63**	**0.2919**	**0.0034**	**15.66**	**0.03**	**59.38**	**0.09**	**5.76**	**0.16**	**24.10**	**0.08**
Case 3	11946	88.02	9.80	0.2306	0.0106	15.53	0.10	58.97	0.40	6.12	0.09	23.65	0.13
Wet Press	11947	113.37	5.20	0.2660	0.0059	15.62	0.06	59.23	0.24	5.85	0.24	23.91	0.16
35 KN/m Calender	11948	101.93	5.52	0.2504	0.0075	15.65	0.05	59.19	0.14	5.72	0.23	23.82	0.07
	11949	99.83	5.52	0.2463	0.0076	15.59	0.09	59.08	0.28	5.77	0.25	23.74	0.14
	Average	**100.79**	**3.39**	**0.2483**	**0.0040**	**15.60**	**0.04**	**59.12**	**0.14**	**5.87**	**0.11**	**23.78**	**0.06**
Case 2	11926	55.64	3.76	0.1847	0.0058	14.11	0.09	57.11	0.52	6.36	0.12	23.99	0.19
246 °C	11930	54.96	2.70	0.1837	0.0042	14.11	0.09	57.07	0.54	6.40	0.03	23.86	0.06
No Calender	11931	54.12	2.33	0.1831	0.0040	14.16	0.09	57.16	0.53	6.34	0.01	23.96	0.09
	11932	54.88	2.74	0.1835	0.0057	14.06	0.06	57.04	0.36	6.37	0.15	23.95	0.05
	Average	**54.90**	**1.47**	**0.1837**	**0.0025**	**14.11**	**0.04**	**57.09**	**0.25**	**6.37**	**0.05**	**23.94**	**0.06**
Case 6	11927	47.41	3.56	0.1689	0.0059	14.03	0.07	57.00	0.42	6.37	0.05	23.97	0.11
246 °C	11928	47.98	2.18	0.1713	0.0040	14.10	0.05	57.09	0.40	6.37	0.20	23.95	0.13
35 KN/m Calender	**Average**	**47.69**	**2.09**	**0.1701**	**0.0036**	**14.06**	**0.05**	**57.05**	**0.29**	**6.37**	**0.10**	**23.96**	**0.08**
Case 4	11933	52.21	1.62	0.1771	0.0028	14.21	0.08	57.14	0.48	6.38	0.16	23.76	0.11
260 °C	11934	52.32	3.25	0.1789	0.0052	14.25	0.10	57.20	0.60	6.29	0.17	23.75	0.22
No Calender	11935	58.09	3.20	0.1873	0.0044	14.25	0.06	57.15	0.39	6.38	0.20	23.68	0.15
	11936	50.53	3.91	0.1760	0.0067	14.18	0.08	57.03	0.45	6.37	0.22	23.65	0.05
	Average	**53.29**	**1.56**	**0.1798**	**0.0025**	**14.22**	**0.04**	**57.13**	**0.24**	**6.36**	**0.10**	**23.71**	**0.07**
Case 1	225111	120.76	6.14	0.2678	0.0070	16.02	0.05	58.62	0.06	6.48	0.08	21.97	0.13
Commercial	225121	131.13	10.29	0.2793	0.0088	16.13	0.05	58.82	0.13	6.37	0.12	22.09	0.17
Lincr - Control	**Average**	**125.94**	**5.99**	**0.2735**	**0.0056**	**16.08**	**0.03**	**58.72**	**0.07**	**6.42**	**0.07**	**22.03**	**0.11**
Commercial	107811												
Medium	107812												
	107813												
	107814												
	107816												
	Average												

Table F2 cont. Average Physical Property Data.

Test Method						T527 (Diffuse)							
	Sample ID (#)	MD FS Emveco Micro Dev.	MD 95% C.I.	MD FS Emveco Micro Ave.	MD 95% C.I.	As Made Color Brightness	95% C.I.	L* Lightness	95% C.I.	a* +Redness -Greeness	95% C.I.	b* +Yellowness -Blueness	95% C.I.
204 °C Roll Temp	11950	62.24	2.72	0.1953	0.0043	13.68	0.08	56.45	0.37	6.50	0.23	24.13	0.22
218 °C Roll Temp	11951	56.85	4.03	0.1882	0.0074	13.57	0.08	56.25	0.51	6.54	0.24	23.98	0.15
232 °C Roll Temp	11952	51.52	1.40	0.1788	0.0024	13.57	0.08	56.20	0.48	6.55	0.22	23.87	0.27
246 °C Roll Temp	11953	53.11	2.34	0.1800	0.0039	13.50	0.06	56.02	0.50	6.54	0.21	23.76	0.11
260 °C Roll Temp	11954	47.28	1.32	0.1706	0.0028	13.81	0.14	56.45	0.83	6.35	0.23	23.72	0.31
274 °C Roll Temp	11955	48.33	2.35	0.1709	0.0039	13.99	0.11	56.69	0.80	6.23	0.24	23.68	0.11
288 °C Roll Temp	11956	45.78	2.75	0.1666	0.0053	14.15	0.08	56.83	0.44	6.09	0.05	23.54	0.10
WP - 43.8 KN/m Cal.	11937												
WP - 37.1 KN/m Cal.	11938												
WP - 10.5 KN/m Cal.	11939												
WP - 28.7 KN/m Cal.	11940												
WP - 19.8 KN/m Cal.	11941												

Table E2 cont. Average Physical Property Data.

Test Method		T527 (Diffuse)							
		Conditioned and Exposed to Light 96 Hours							
	Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	95% C.I.	a* +Redness -Greeness	95% C.I.	b* +Yellowness -Blueness	95% C.I.
Case 5	11942	14.92	0.06	57.83	0.24	7.07	0.10	21.78	0.09
Wet Press	11943	14.93	0.05	57.79	0.14	7.17	0.15	21.70	0.15
No Calender	11944	14.97	0.05	57.84	0.19	7.15	0.10	21.66	0.21
	11945	14.97	0.04	57.84	0.19	7.18	0.15	21.67	0.07
	Average	**14.94**	**0.03**	**57.83**	**0.10**	**7.14**	**0.06**	**21.70**	**0.07**
Case 3	11946	15.06	0.13	57.97	0.59	6.92	0.13	21.74	0.17
Wet Press	11947	14.96	0.08	57.82	0.17	7.07	0.02	21.74	0.14
35 KN/m Calender	11948	15.22	0.16	58.14	0.62	6.93	0.26	21.68	0.22
	11949	15.23	0.13	58.17	0.62	6.88	0.26	21.78	0.35
	Average	**15.12**	**0.06**	**58.03**	**0.27**	**6.95**	**0.10**	**21.74**	**0.12**
Case 2	11926	13.11	0.07	55.23	0.48	7.28	0.19	22.94	0.31
246 °C	11930	13.15	0.08	55.16	0.30	7.18	0.08	22.78	0.09
No Calender	11931	13.36	0.07	55.47	0.40	7.20	0.23	22.71	0.17
	11932	13.38	0.04	55.46	0.09	7.19	0.19	22.67	0.18
	Average	**13.25**	**0.03**	**55.33**	**0.17**	**7.21**	**0.09**	**22.78**	**0.10**
Case 6	11927	13.15	0.08	55.32	0.44	7.13	0.09	23.06	0.16
246 °C	11928	13.18	0.09	55.36	0.46	7.21	0.18	22.96	0.14
35 KN/m Calender	**Average**	**13.16**	**0.06**	**55.34**	**0.32**	**7.17**	**0.10**	**23.01**	**0.11**
Case 4	11933	13.48	0.06	55.54	0.26	7.10	0.25	22.52	0.17
260 °C	11934	13.32	0.08	55.39	0.47	7.12	0.09	22.70	0.18
No Calender	11935	13.58	0.10	55.67	0.53	7.15	0.34	22.48	0.20
	11936	13.64	0.08	55.81	0.49	7.47	0.09	21.40	0.09
	Average	**13.50**	**0.04**	**55.60**	**0.22**	**7.21**	**0.11**	**22.28**	**0.08**
Case 1	225111	15.93	0.03	58.78	0.12	6.52	0.06	21.14	0.09
Commercial	225121	15.90	0.05	58.71	0.10	6.53	0.03	21.00	0.20
Liner - Control	**Average**	**15.91**	**0.03**	**58.74**	**0.08**	**6.53**	**0.04**	**21.07**	**0.11**
Commercial	107811								
Medium	107812								
	107813								
	107814								
	107816								
	Average								

Table E2 cont. Average Physical Property Data.

Test Method		T527 (Diffuse)							
		Conditioned and Exposed to Light 96 Hours							
	Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	95% C.I.	a* +Redness -Greeness	95% C.I.	b* +Yellowness -Blueness	95% C.I.
204 °C Roll Temp	11950	13.04	0.05	55.10	0.22	7.53	0.22	21.71	0.14
218 °C Roll Temp	11951	12.99	0.07	54.97	0.32	7.57	0.19	21.61	0.09
232 °C Roll Temp	11952	13.00	0.07	54.97	0.39	7.54	0.07	21.60	0.19
246 °C Roll Temp	11953	12.90	0.08	54.68	0.43	7.51	0.11	21.30	0.14
260 °C Roll Temp	11954	13.28	0.10	55.20	0.65	7.31	0.32	21.24	0.14
274 °C Roll Temp	11955	13.40	0.08	55.35	0.33	7.26	0.09	21.24	0.11
288 °C Roll Temp	11956	13.44	0.06	55.35	0.20	7.20	0.13	21.12	0.19
WP - 43.8 KN/m Cal.	11937								
WP - 37.1 KN/m Cal.	11938								
WP - 10.5 KN/m Cal.	11939								
WP - 28.7 KN/m Cal.	11940								
WP - 19.8 KN/m Cal.	11941								

Table E2 cont. Average Physical Property Data.

Test Method		T524 (Directional)								T480		T441			
		Conditioned and Exposed to Light 96 Hours													
	Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	95% C.I.	a* +Redness -Greeness	95% C.I.	b* +Yellowness -Blueness	95% C.I.	Gloss	95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.
Case 5	11942	15.20	0.18	58.47	0.69	6.66	0.33	22.33	0.19	7.43	0.24	372.9	4.3	366.3	8.6
Wet Press	11943	15.23	0.13	58.48	0.22	6.77	0.04	22.28	0.19	7.15	0.08	326.1	5.4	320.8	6.4
No Calender	11944	15.27	0.11	58.51	0.44	6.80	0.21	22.24	0.13	7.19	0.11	337.0	5.6	335.7	5.0
	11945	15.12	0.17	58.32	0.43	6.80	0.08	22.27	0.29	7.20	0.07	336.2	7.4	328.7	8.2
	Average	**15.20**	**0.08**	**58.45**	**0.24**	**6.76**	**0.10**	**22.28**	**0.10**	**7.24**	**0.07**	**343.1**	**2.9**	**337.9**	**3.6**
Case 3	11946	15.76	0.24	59.17	0.80	6.68	0.09	22.35	0.12	9.09	0.13	317.3	6.0	315.6	4.1
Wet Press	11947	15.33	0.15	58.69	0.24	6.81	0.25	22.43	0.07	7.97	0.28	359.7	8.2	364.9	6.8
35 KN/m Calender	11948	15.92	0.19	59.35	0.35	6.61	0.17	22.21	0.19	8.90	0.18	314.7	4.0	313.0	6.4
	11949	16.03	0.18	59.55	0.60	6.54	0.13	22.29	0.11	9.06	0.12	312.8	5.0	303.2	8.8
	Average	**15.76**	**0.10**	**59.19**	**0.27**	**6.66**	**0.09**	**22.32**	**0.07**	**8.76**	**0.09**	**326.1**	**3.0**	**324.2**	**3.4**
Case 2	11926	13.47	0.13	55.97	0.54	7.40	0.18	22.14	0.01	12.71	0.17	304.7	9.4	297.2	7.4
246 °C	11930	13.47	0.14	55.82	0.26	7.33	0.22	21.94	0.13	12.02	0.17	301.6	6.2	301.8	5.5
No Calender	11931	13.36	0.13	55.73	0.40	7.37	0.10	22.05	0.07	12.03	0.17	285.4	7.8	290.4	8.4
	11932	13.62	0.13	56.02	0.45	7.26	0.11	21.91	0.11	12.13	0.16	288.4	9.3	299.0	11.8
	Average	**13.48**	**0.07**	**55.88**	**0.21**	**7.34**	**0.08**	**22.01**	**0.05**	**12.22**	**0.08**	**295.0**	**4.1**	**297.1**	**4.3**
Case 6	11927	13.55	0.17	56.05	0.40	7.36	0.15	22.17	0.21	13.15	0.27	293.8	2.7	295.0	4.8
246 °C	11928	13.41	0.14	55.89	0.62	7.35	0.14	22.21	0.13	12.93	0.18	291.7	6.0	293.9	6.8
35 KN/m Calender	**Average**	**13.48**	**0.11**	**55.97**	**0.37**	**7.36**	**0.10**	**22.19**	**0.12**	**13.04**	**0.16**	**292.8**	**3.3**	**294.5**	**4.2**
Case 4	11933	13.68	0.15	56.05	0.34	7.23	0.17	21.80	0.16	13.63	0.22	300.3	4.8	294.8	6.0
260 °C	11934	13.70	0.17	56.12	0.48	7.24	0.08	21.84	0.20	13.38	0.37	308.2	5.8	309.4	8.8
No Calender	11935	13.76	0.17	56.18	0.53	7.18	0.13	21.83	0.19	13.24	0.23	301.0	6.3	295.4	5.5
	11936	13.78	0.17	56.34	0.92	7.10	0.20	22.03	0.08	13.48	0.16	289.0	8.7	270.7	6.4
	Average	**13.73**	**0.08**	**56.17**	**0.30**	**7.19**	**0.08**	**21.88**	**0.08**	**13.43**	**0.13**	**299.6**	**3.3**	**292.6**	**3.4**
Case 1	225111	15.93	0.03	58.78	0.12	6.52	0.06	21.14	0.09	16.03	0.18	38.8	2.1	55.4	4.2
Commercial	225121	15.90	0.05	58.71	0.10	6.53	0.03	21.00	0.20	15.87	0.21	43.4	3.5	63.9	3.8
Liner - Control	**Average**	**15.91**	**0.03**	**58.74**	**0.08**	**6.53**	**0.04**	**21.07**	**0.11**	**15.95**	**0.14**	**41.1**	**2.1**	**59.7**	**2.8**
Commercial	107811											208.8	5.1	211.6	4.9
Medium	107812											216.0	4.6	219.3	3.3
	107813											203.1	5.9	203.7	8.4
	107814											224.2	7.4	243.4	13.8
	107816											255.8	12.3	233.1	11.0
	Average											**221.6**	**3.4**	**222.2**	**4.1**

Table E2 cont. Average Physical Property Data.

Test Method		T524 (Directional)								T480		T441			
		Conditioned and Exposed to Light 96 Hours													
	Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	95% C.I.	a* +Redness -Greeness	95% C.I.	b* +Yellowness -Blueness	95% C.I.	Gloss	95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.
204 °C Roll Temp	11950	13.07	0.18	55.44	0.72	7.34	0.29	22.30	0.27	10.89	0.13	330.2	8.0	332.5	5.0
218 °C Roll Temp	11951	13.17	0.11	55.50	0.48	7.28	0.26	22.15	0.20	11.69	0.19	316.5	5.7	319.4	8.6
232 °C Roll Temp	11952	13.01	0.14	55.27	0.46	7.36	0.24	22.13	0.22	12.48	0.18	306.6	6.7	309.7	7.2
246 °C Roll Temp	11953	13.08	0.16	55.25	0.41	7.26	0.17	21.95	0.06	13.53	0.20	311.4	7.4	305.2	8.6
260 °C Roll Temp	11954	13.29	0.19	55.59	0.90	7.09	0.26	21.98	0.11	14.97	0.23	305.5	6.8	311.8	8.5
274 °C Roll Temp	11955	13.42	0.15	55.76	0.14	7.11	0.08	21.97	0.10	15.85	0.26	310.9	6.8	315.6	6.9
288 °C Roll Temp	11956	13.36	0.17	55.65	0.42	7.06	0.10	21.91	0.13	17.46	0.19	293.6	6.7	300.2	5.1
WP - 43.8 KN/m Cal.	11937														
WP - 37.1 KN/m Cal.	11938														
WP - 10.5 KN/m Cal.	11939														
WP - 28.7 KN/m Cal.	11940														
WP - 19.8 KN/m Cal.	11941														

Table E2 cont. Average Physical Property Data.

Test Method		T403				IPST				T826			
	Sample ID (#)	Mullen Burst (psi)	95% C.I.	Mullen Burst (kPa)	95% C.I.	MD Crack Angle (deg)	95% C.I.	CD Crack Angle (deg)	95% C.I.	CD STFI (lbf/in)	95% C.I.	MD STFI (lbf/in)	95% C.I.
Case 5	11942	67.2	2.6	463.4	18.3	64.4	4.2	77.3	5.3	14.89	0.38	27.08	0.54
Wet Press	11943	66.3	2.1	457.1	14.8	63.1	2.8	66.4	5.4	15.34	0.38	26.73	0.48
No Calender	11944	67.2	2.6	463.6	17.7	66.0	3.5	71.0	6.3	15.79	0.38	27.11	0.48
	11945	66.2	3.0	456.2	20.4	66.7	2.2	47.5	7.9	15.16	0.42	26.64	0.45
	Average	**66.7**	**1.3**	**460.1**	**8.9**	**65.1**	**1.6**	**65.6**	**3.2**	**15.30**	**0.20**	**26.89**	**0.24**
Case 3	11946	65.7	2.0	452.8	14.0	73.8	3.1	74.1	3.9	15.37	0.34	27.12	0.51
Wet Press	11947	64.3	2.3	443.0	15.9	64.5	4.6	70.2	4.7	14.73	0.29	26.31	0.48
35 KN/m Calender	11948	63.7	2.2	439.5	15.4	68.8	2.3	71.0	5.6	15.22	0.36	26.89	0.39
	11949	64.4	2.6	444.3	18.2	69.0	3.2	68.3	5.2	14.82	0.32	25.92	0.44
	Average	**64.5**	**1.2**	**444.9**	**8.0**	**69.0**	**1.7**	**70.9**	**2.4**	**15.03**	**0.16**	**26.56**	**0.23**
Case 2	11926	78.6	2.4	541.9	16.3	65.3	3.7	71.2	5.6	16.60	0.39	27.61	0.58
246 °C	11930	77.9	2.1	537.1	14.6	69.8	2.5	72.1	3.5	16.66	0.37	29.83	0.53
No Calender	11931	78.6	2.6	542.0	17.8	64.6	4.5	66.1	2.6	16.66	0.38	29.71	0.49
	11932	77.5	2.0	534.2	13.6	71.9	2.7	69.7	4.2	16.31	0.36	28.58	0.54
	Average	**78.1**	**1.1**	**538.8**	**7.8**	**67.9**	**1.7**	**69.8**	**2.1**	**16.56**	**0.19**	**28.93**	**0.27**
Case 6	11927	76.7	2.8	529.0	19.2	64.6	2.9	65.8	4.0	16.36	0.34	28.45	0.50
246 °C	11928	77.9	2.7	537.3	18.5	68.2	2.9	65.3	4.4	16.49	0.41	29.34	0.52
35 KN/m Calender	**Average**	**77.3**	**1.9**	**533.2**	**13.4**	**66.4**	**2.1**	**65.6**	**3.0**	**16.42**	**0.27**	**28.89**	**0.36**
Case 4	11933	73.6	2.5	507.3	17.1	58.0	2.5	70.3	3.4	16.27	0.42	28.10	0.49
260 °C	11934	75.2	2.4	518.7	16.9	69.3	2.9	69.3	4.0	16.62	0.36	29.19	0.53
No Calender	11935	78.0	2.6	537.9	18.2	71.3	2.4	70.4	3.6	16.56	0.28	29.67	0.51
	11936	75.3	2.7	519.3	18.9	69.8	3.0	69.1	4.5	16.74	0.42	30.16	0.47
	Average	**75.5**	**1.3**	**520.8**	**8.9**	**67.1**	**1.4**	**69.8**	**1.9**	**16.55**	**0.19**	**29.28**	**0.25**
Case 1	225111	85.0	3.6	586.4	24.7	70.2	2.8	84.2	3.4	17.88	0.38	32.88	0.65
Commercial	225121	81.3	2.7	560.6	18.3	72.8	2.9	83.9	4.4	18.12	0.42	33.19	0.58
Liner - Control	**Average**	**83.2**	**2.2**	**573.5**	**15.4**	**71.5**	**2.0**	**84.1**	**2.8**	**18.00**	**0.28**	**33.04**	**0.43**
Commercial	107811	35.4	0.8	244.2	5.8					11.06	0.24	21.31	0.55
Medium	107812	34.7	1.0	239.1	7.0					10.95	0.24	20.02	0.30
	107813	35.3	1.3	243.4	8.7					10.72	0.21	20.47	0.32
	107814	35.1	1.1	242.3	7.7					11.02	0.17	20.82	0.46
	107816	35.4	1.2	243.9	8.3					10.91	0.17	21.18	0.36
	Average	**35.2**	**0.5**	**242.6**	**3.4**					**10.93**	**0.09**	**20.76**	**0.18**

Table E2 cont. Average Physical Property Data.

Test Method		T403				IPST				T826			
	Sample ID (#)	Mullen Burst (psi)	95% C.I.	Mullen Burst (kPa)	95% C.I.	MD Crack Angle (deg)	95% C.I.	CD Crack Angle (deg)	95% C.I.	CD STFI (lbf/in)	95% C.I.	MD STFI (lbf/in)	95% C.I.
204 °C Roll Temp	11950	68.3	2.4	470.9	16.7	74.1	3.9	81.1	4.3	15.83	0.28	27.62	0.38
218 °C Roll Temp	11951	69.2	2.3	477.2	15.6	68.5	3.7	67.1	5.8	16.07	0.32	28.41	0.36
232 °C Roll Temp	11952	67.8	2.5	467.3	17.2	71.1	5.5	67.4	7.6	15.54	0.26	27.51	0.38
246 °C Roll Temp	11953	69.8	2.7	481.1	18.8	79.6	3.0	83.7	4.4	15.76	0.30	27.55	0.37
260 °C Roll Temp	11954	70.7	2.4	487.7	16.7	72.4	2.1	75.4	3.3	16.34	0.30	28.27	0.34
274 °C Roll Temp	11955	71.8	2.5	495.2	17.2	74.0	3.9	72.5	3.7	16.33	0.35	28.27	0.49
288 °C Roll Temp	11956	72.2	2.3	497.7	15.8	77.3	3.7	80.5	3.9	15.98	0.32	28.74	0.45
WP - 43.8 KN/m Cal.	11937												
WP - 37.1 KN/m Cal.	11938												
WP - 10.5 KN/m Cal.	11939												
WP - 28.7 KN/m Cal.	11940												
WP - 19.8 KN/m Cal.	11941												

Table E2 cont. Average Physical Property Data.

Test Method								T822							
	Sample ID (#)	CD STFI Index (N*m/g)	95% C.I.	MD STFI Index (N*m/g)	95% C.I.	Geo Mean STFI Index (N*m/g)	95% C.I.	CD Ring Crush (lbf)	95% C.I.	MD Ring Crush (lbf)	95% C.I.	CD R. C. Index (N*m/g)	95% C.I.	MD R. C. Index (N*m/g)	95% C.I.
Case 5	11942	17.32	0.44	31.10	0.62	23.20	0.42	9.19	0.19	13.02	0.21	10.63	0.20	15.05	0.25
Wet Press	11943	18.32	0.44	31.58	0.58	24.05	0.39	9.25	0.15	13.16	0.18	10.95	0.18	15.57	0.21
No Calender	11944	17.81	0.41	30.60	0.55	23.34	0.36	9.32	0.17	13.19	0.15	10.57	0.18	15.00	0.16
	11945	17.11	0.46	30.10	0.53	22.69	0.41	9.25	0.25	13.27	0.20	10.49	0.26	15.13	0.23
	Average	**17.64**	**0.22**	**30.85**	**0.29**	**23.32**	**0.20**	**9.25**	**0.10**	**13.16**	**0.09**	**10.66**	**0.10**	**15.19**	**0.11**
Case 3	11946	17.82	0.36	31.36	0.57	23.63	0.36	9.02	0.20	12.86	0.26	10.51	0.21	14.88	0.25
Wet Press	11947	17.24	0.34	30.38	0.59	22.88	0.32	9.03	0.19	13.01	0.26	10.51	0.22	15.19	0.29
35 KN/m Calender	11948	17.76	0.39	31.26	0.47	23.56	0.32	8.84	0.20	12.78	0.27	10.33	0.23	14.95	0.31
	11949	17.40	0.37	29.99	0.50	22.84	0.35	8.83	0.23	12.67	0.23	10.24	0.26	14.67	0.24
	Average	**17.56**	**0.18**	**30.75**	**0.27**	**23.23**	**0.17**	**8.93**	**0.10**	**12.83**	**0.13**	**10.40**	**0.12**	**14.92**	**0.14**
Case 2	11926	19.43	0.43	32.19	0.67	25.00	0.41	10.19	0.15	14.56	0.41	11.88	0.15	17.03	0.50
246 °C	11930	19.11	0.43	33.88	0.59	25.43	0.37	10.43	0.17	14.99	0.26	11.95	0.20	17.29	0.30
No Calender	11931	19.67	0.44	34.75	0.56	26.14	0.40	10.07	0.23	14.54	0.17	11.79	0.28	17.11	0.21
	11932	19.27	0.42	33.46	0.63	25.39	0.38	10.02	0.19	14.52	0.23	11.88	0.22	17.18	0.27
	Average	**19.37**	**0.22**	**33.57**	**0.31**	**25.49**	**0.20**	**10.18**	**0.09**	**14.65**	**0.14**	**11.87**	**0.11**	**17.15**	**0.17**
Case 6	11927	19.16	0.40	33.61	0.58	25.38	0.39	10.20	0.23	14.81	0.16	11.91	0.25	17.36	0.21
246 °C	11928	19.27	0.48	34.00	0.60	25.59	0.43	10.10	0.17	14.61	0.19	11.73	0.18	16.97	0.20
35 KN/m Calender	**Average**	**19.21**	**0.31**	**33.81**	**0.42**	**25.48**	**0.29**	**10.15**	**0.14**	**14.71**	**0.13**	**11.82**	**0.16**	**17.16**	**0.15**
Case 4	11933	19.29	0.50	33.75	0.57	25.50	0.40	10.02	0.20	14.49	0.26	11.84	0.22	17.29	0.27
260 °C	11934	19.40	0.41	33.96	0.63	25.66	0.40	10.12	0.23	14.69	0.29	11.74	0.24	17.17	0.33
No Calender	11935	19.19	0.32	34.23	0.60	25.63	0.32	10.50	0.16	15.10	0.23	12.07	0.18	17.37	0.28
	11936	19.53	0.49	34.86	0.52	26.08	0.41	10.14	0.20	14.64	0.20	11.82	0.20	17.15	0.23
	Average	**19.35**	**0.22**	**34.20**	**0.29**	**25.72**	**0.19**	**10.19**	**0.10**	**14.73**	**0.12**	**11.87**	**0.11**	**17.24**	**0.14**
Case 1	225111	21.58	0.45	39.22	0.76	29.09	0.43	10.10	0.31	14.26	0.34	11.89	0.32	16.91	0.31
Commercial	225121	21.58	0.51	39.76	0.70	29.29	0.48	10.47	0.30	14.37	0.23	12.21	0.36	16.82	0.27
Liner - Control	**Average**	**21.58**	**0.34**	**39.49**	**0.51**	**29.19**	**0.32**	**10.28**	**0.22**	**14.31**	**0.21**	**12.05**	**0.24**	**16.87**	**0.20**
Commercial	107811	16.56	0.34	31.58	0.76	22.86	0.39	5.30	0.12	7.92	0.23	7.97	0.15	11.78	0.26
Medium	107812	16.73	0.36	30.81	0.41	22.70	0.32	5.08	0.17	7.22	0.19	7.78	0.24	10.98	0.26
	107813	16.44	0.31	31.43	0.48	22.73	0.30	4.73	0.17	7.39	0.13	7.32	0.22	11.25	0.18
	107814	16.54	0.27	30.79	0.55	22.56	0.25	5.20	0.14	7.97	0.15	7.83	0.18	11.91	0.20
	107816	16.61	0.22	31.95	0.51	23.03	0.24	4.93	0.14	7.69	0.18	7.60	0.18	11.65	0.22
	Average	**16.58**	**0.14**	**31.31**	**0.25**	**22.78**	**0.14**	**5.05**	**0.07**	**7.64**	**0.08**	**7.70**	**0.09**	**11.51**	**0.10**

Table E2 cont. Average Physical Property Data.

Test Method								T822							
	Sample ID (#)	CD STFI Index (N*m/g)	95% C.I.	MD STFI Index (N*m/g)	95% C.I.	Geo Mean STFI Index (N*m/g)	95% C.I.	CD Ring Crush (lbf)	95% C.I.	MD Ring Crush (lbf)	95% C.I.	CD R. C. Index (N*m/g)	95% C.I.	MD R. C. Index (N*m/g)	95% C.I.
204 °C Roll Temp	11950	18.55	0.33	32.26	0.46	24.46	0.32	9.47	0.16	13.17	0.29	11.09	0.18	15.38	0.35
218 °C Roll Temp	11951	18.76	0.37	33.41	0.44	25.03	0.32	9.54	0.20	13.18	0.25	11.19	0.22	15.42	0.30
232 °C Roll Temp	11952	18.55	0.30	32.82	0.46	24.67	0.29	9.34	0.11	12.94	0.15	11.11	0.11	15.40	0.16
246 °C Roll Temp	11953	18.29	0.34	32.20	0.45	24.26	0.30	9.40	0.09	13.29	0.10	11.04	0.10	15.64	0.12
260 °C Roll Temp	11954	18.83	0.34	32.89	0.40	24.88	0.31	9.85	0.09	13.57	0.11	11.34	0.10	15.70	0.12
274 °C Roll Temp	11955	18.76	0.40	32.50	0.57	24.68	0.38	9.43	0.14	12.68	0.16	10.80	0.16	14.62	0.16
288 °C Roll Temp	11956	18.60	0.38	33.50	0.50	24.96	0.34	8.72	0.13	12.06	0.16	10.11	0.14	13.92	0.18
WP - 43.8 KN/m Cal.	11937														
WP - 37.1 KN/m Cal.	11938														
WP - 10.5 KN/m Cal.	11939														
WP - 28.7 KN/m Cal.	11940														
WP - 19.8 KN/m Cal.	11941														

Table E2 cont. Average Physical Property Data.

Test Method		T494								T494			
	Sample ID (#)	CD Tensile (lbf/in)	95% C.I.	MD Tensile (lbf/in)	95% C.I.	CD Tensile Index (N*m/g)	95% C.I.	MD Tensile Index (N*m/g)	95% C.I.	CD Young's Modulus (lbf/in^2)	95% C.I.	MD Young's Modulus (lbf/in^2)	95% C.I.
Case 5	11942	23.75	0.41	59.63	1.13	27.30	0.50	68.08	1.27	20081	388	53069	1361
Wet Press	11943	23.53	0.52	57.11	1.20	27.80	0.56	67.31	1.47	19107	405	51404	869
No Calender	11944	24.20	0.42	60.48	0.97	27.41	0.45	68.06	1.10	20318	322	52607	986
	11945	23.63	0.37	58.95	1.12	27.07	0.45	67.02	1.18	20436	255	53391	697
	Average	**23.78**	**0.22**	**59.04**	**0.55**	**27.40**	**0.25**	**67.62**	**0.63**	**19985**	**174**	**52618**	**504**
Case 3	11946	23.74	0.42	58.77	1.17	27.26	0.48	67.89	1.25	19632	430	55338	2971
Wet Press	11947	23.32	0.39	57.71	1.16	27.31	0.46	67.52	1.25	19223	461	52869	828
35 KN/m Calender	11948	23.38	0.47	57.95	1.14	27.19	0.53	67.66	1.26	19229	267	51132	590
	11949	23.10	0.42	58.12	0.94	26.71	0.47	67.24	1.18	18674	287	49830	550
	Average	**23.39**	**0.21**	**58.14**	**0.55**	**27.12**	**0.24**	**67.58**	**0.62**	**19189**	**186**	**52292**	**797**
Case 2	11926	26.79	0.71	67.66	1.20	31.24	0.75	79.10	1.51	21592	463	56515	989
246 °C	11930	27.31	0.67	67.47	1.23	31.40	0.74	77.44	1.50	21419	404	53338	2994
No Calender	11931	26.98	0.49	67.40	1.17	31.81	0.60	79.64	1.39	20462	451	54203	1085
	11932	26.79	0.64	68.29	1.03	31.85	0.76	81.08	1.06	20354	407	53875	1073
	Average	**26.97**	**0.32**	**67.71**	**0.58**	**31.57**	**0.36**	**79.32**	**0.69**	**20957**	**216**	**54483**	**876**
Case 6	11927	26.96	0.59	67.21	1.13	31.72	0.72	78.62	1.26	20997	394	55511	964
246 °C	11928	27.20	0.51	67.10	1.37	31.53	0.62	77.78	1.50	20963	443	56186	942
35 KN/m Calender	**Average**	**27.08**	**0.39**	**67.16**	**0.89**	**31.62**	**0.47**	**78.20**	**0.98**	**20980**	**296**	**55849**	**674**
Case 4	11933	26.23	0.64	66.54	1.16	31.10	0.75	79.42	1.32	20731	475	56241	773
260 °C	11934	27.02	0.80	68.68	1.05	31.31	0.82	79.62	1.16	19886	740	54698	1030
No Calender	11935	27.33	0.53	68.81	1.15	31.55	0.62	79.39	1.34	20714	301	51786	685
	11936	26.44	0.56	68.29	1.05	30.92	0.64	79.65	1.10	20634	335	52409	585
	Average	**26.75**	**0.32**	**68.08**	**0.55**	**31.22**	**0.36**	**79.52**	**0.62**	**20491**	**247**	**53784**	**393**
Case 1	225111	26.99	0.55	75.61	2.22	32.72	0.71	91.33	2.28	18888	340	59413	1432
Commercial	225121	26.00	0.71	75.96	1.53	30.85	0.92	88.90	2.09	18140	753	53794	1052
Liner - Control	**Average**	**26.50**	**0.45**	**75.78**	**1.35**	**31.78**	**0.58**	**90.11**	**1.55**	**18514**	**413**	**56604**	**888**
Commercial	107811	12.44	0.20	37.07	0.66	18.88	0.25	55.76	0.88	10569	159	36430	534
Medium	107812	12.83	0.15	35.92	0.71	19.53	0.20	54.77	0.99	10358	189	35496	504
	107813	12.03	0.20	34.77	1.01	18.48	0.30	53.26	1.32	9720	191	33436	727
	107814	12.42	0.19	37.75	0.81	18.79	0.28	56.99	0.85	10163	164	36608	865
	107816	12.50	0.19	36.01	0.89	19.01	0.29	54.94	1.19	10299	336	36406	930
	Average	**12.44**	**0.08**	**36.30**	**0.37**	**18.94**	**0.12**	**55.14**	**0.48**	**10222**	**97**	**35675**	**327**

Table E2 cont. Average Physical Property Data.

Test Method		T494								T494			
	Sample ID (#)	CD Tensile (lbf/in)	95% C.I.	MD Tensile (lbf/in)	95% C.I.	CD Tensile Index (N*m/g)	95% C.I.	MD Tensile Index (N*m/g)	95% C.I.	CD Young's Modulus (lbf/in^2)	95% C.I.	MD Young's Modulus (lbf/in^2)	95% C.I.
204 °C Roll Temp	11950	24.71	0.44	60.90	2.50	28.98	0.55	71.38	2.91	20659	224	51581	1249
218 °C Roll Temp	11951	25.03	0.53	61.59	1.08	29.34	0.61	72.03	1.22	19312	503	52750	1360
232 °C Roll Temp	11952	24.66	0.46	62.08	1.03	29.24	0.55	73.93	1.22	20472	237	53513	1057
246 °C Roll Temp	11953	24.95	0.47	62.08	1.00	29.49	0.56	73.87	1.12	20081	276	52563	682
260 °C Roll Temp	11954	25.61	0.54	63.89	1.40	29.73	0.60	74.07	1.59	20668	368	52402	2542
274 °C Roll Temp	11955	25.69	0.54	63.81	0.96	29.57	0.61	73.64	1.18	20171	346	53672	825
288 °C Roll Temp	11956	25.90	0.46	64.08	1.19	30.36	0.51	74.62	1.27	19638	343	53220	669
WP - 43.8 KN/m Cal.	11937												
WP - 37.1 KN/m Cal.	11938												
WP - 10.5 KN/m Cal.	11939												
WP - 28.7 KN/m Cal.	11940												
WP - 19.8 KN/m Cal.	11941												

Table E2 cont. Average Physical Property Data.

Test Method						IPST		IPST		T809			
	Sample ID (#)	CD Young's Modulus (MN/m^2)	95% C.I.	MD Young's Modulus (MN/m^2)	95% C.I.	OD Basis Weight (g/m^2)	95% C.I.	OD Density (g/cm^3)	95% C.I.	Concora (lbf)	95% C.I.	Concora (N)	95% C.I.
Case 5	11942	138.4	2.7	365.9	9.4	152.0	0.4	0.624	0.007				
Wet Press	11943	131.7	2.8	354.4	6.0	148.1	0.4	0.622	0.007				
No Calender	11944	140.1	2.2	362.7	6.8	154.7	0.4	0.627	0.008				
	11945	140.9	1.8	368.1	4.8	153.8	0.4	0.615	0.007				
	Average	**137.8**	**1.2**	**362.8**	**3.5**	**152.1**	**0.2**	**0.622**	**0.004**				
Case 3	11946	135.3	3.0	381.5	20.5	151.3	0.3	0.634	0.005				
Wet Press	11947	132.5	3.2	364.5	5.7	150.0	0.3	0.634	0.005				
35 KN/m Calender	11948	132.6	1.8	352.5	4.1	150.0	0.4	0.631	0.007				
	11949	128.7	2.0	343.5	3.8	151.1	0.4	0.632	0.007				
	Average	**132.3**	**1.3**	**360.5**	**5.5**	**150.6**	**0.2**	**0.633**	**0.003**				
Case 2	11926	148.9	3.2	389.6	6.8	150.0	0.3	0.693	0.010				
246 °C	11930	147.7	2.8	367.7	20.6	152.5	0.4	0.698	0.011				
No Calender	11931	141.1	3.1	373.7	7.5	148.9	0.4	0.687	0.010				
	11932	140.3	2.8	371.4	7.4	147.7	0.4	0.680	0.016				
	Average	**144.5**	**1.5**	**375.6**	**6.0**	**149.8**	**0.2**	**0.689**	**0.006**				
Case 6	11927	144.8	2.7	382.7	6.6	149.4	0.3	0.728	0.006				
246 °C	11928	144.5	3.1	387.4	6.5	150.9	0.3	0.715	0.007				
35 KN/m Calender	**Average**	**144.6**	**2.0**	**385.0**	**4.6**	**150.1**	**0.2**	**0.721**	**0.005**				
Case 4	11933	142.9	3.3	387.7	5.3	147.3	0.4	0.685	0.012				
260 °C	11934	137.1	5.1	377.1	7.1	150.6	0.4	0.672	0.011				
No Calender	11935	142.8	2.1	357.0	4.7	152.0	0.3	0.694	0.009				
	11936	142.3	2.3	361.3	4.0	150.0	0.3	0.701	0.010				
	Average	**141.3**	**1.7**	**370.8**	**2.7**	**150.0**	**0.2**	**0.688**	**0.005**				
Case 1	225111	130.2	2.3	409.6	9.9	146.4	0.6	0.701	0.008				
Commercial	225121	125.1	5.2	370.9	7.3	147.1	9.4	0.698	0.046				
Liner - Control	**Average**	**127.6**	**2.8**	**390.2**	**6.1**	**146.8**	**4.7**	**0.700**	**0.023**				
Commercial	107811	72.9	1.1	251.2	3.7	116.5	0.4	0.616	0.007	49.83	1.08	221.7	4.8
Medium	107812	71.4	1.3	244.7	3.5	115.0	1.9	0.631	0.012	48.72	0.92	216.7	4.1
	107813	67.0	1.3	230.5	5.0	114.1	0.4	0.633	0.007	49.40	1.29	219.7	5.7
	107814	70.1	1.1	252.4	6.0	116.4	0.5	0.613	0.007	48.30	1.41	214.8	6.3
	107816	71.0	2.3	251.0	6.4	114.8	0.4	0.620	0.007	51.13	1.40	227.4	6.2
	Average	**70.5**	**0.7**	**246.0**	**2.3**	**115.4**	**0.4**	**0.623**	**0.004**	**49.48**	**0.55**	**220.1**	**2.5**

Table E2 cont. Average Physical Property Data.

Test Method						IPST		IPST		T809			
	Sample ID (#)	CD Young's Modulus (MN/m^2)	95% C.I.	MD Young's Modulus (MN/m^2)	95% C.I.	OD Basis Weight (g/m^2)	95% C.I.	OD Density (g/cm^3)	95% C.I.	Concora (lbf)	95% C.I.	Concora (N)	95% C.I.
204 °C Roll Temp	11950	142.4	1.5	355.6	8.6	149.6	0.3	0.651	0.007				
218 °C Roll Temp	11951	133.1	3.5	363.7	9.4	149.5	0.3	0.678	0.008				
232 °C Roll Temp	11952	141.1	1.6	368.9	7.3	147.1	0.2	0.684	0.008				
246 °C Roll Temp	11953	138.4	1.9	362.4	4.7	149.1	0.3	0.684	0.008				
260 °C Roll Temp	11954	142.5	2.5	361.3	17.5	151.6	0.3	0.686	0.008				
274 °C Roll Temp	11955	139.1	2.4	370.0	5.7	152.3	0.3	0.654	0.009				
288 °C Roll Temp	11956	135.4	2.4	366.9	4.6	150.8	0.3	0.669	0.009				
WP - 43.8 KN/m Cal.	11937												
WP - 37.1 KN/m Cal.	11938												
WP - 10.5 KN/m Cal.	11939												
WP - 28.7 KN/m Cal.	11940												
WP - 19.8 KN/m Cal.	11941												

Table E3. Average Physical Property Data by Lane.

Test Methods	IPST		IPST				T460		UM535				T538	
Sample ID (#)	ZD-Long. SEM (MN m/kg)	95% C.I.	Soft Caliper (microns)	95% C.I.	Soft Caliper (mills)	95% C.I.	Gurley Porosity (s/100ml)	95% C.I.	FS Bendtsen Roughness (ml/min)	95% C.I.	WS Bendtsen Roughness (ml/min)	95% C.I.	FS Sheffield Roughness (SU)	95% C.I.
11926														
Front	0.1398	0.0050	218.47	5.00	8.60	0.20	24.96	0.46	1816	105	2343	105	402	7
Center	0.1229	0.0029	217.23	4.66	8.55	0.18	21.30	0.46	1908	139	2284	100	404	9
Back	0.1363	0.0050	224.67	7.05	8.85	0.28	23.44	0.64	1916	111	2282	114	403	7
11927														
Front	0.1288	0.0048	205.20	2.11	8.08	0.08	25.91	0.95	1506	107	1859	80	376	11
Center	0.1036	0.0034	206.17	2.36	8.12	0.09	22.35	0.53	1150	106	1723	82	350	10
Back	0.1129	0.0038	207.27	2.68	8.16	0.11	24.92	0.82	1269	139	1749	118	365	10
11928														
Front	0.1360	0.0069	210.83	3.10	8.30	0.12	26.21	1.00	1430	102	1770	87	378	7
Center	0.1099	0.0049	209.57	2.17	8.25	0.09	24.48	0.99	1105	84	1782	61	350	11
Back	0.1190	0.0051	210.97	3.52	8.31	0.14	25.66	0.99	1243	95	1651	78	356	8
11930														
Front	0.1469	0.0046	210.20	3.33	8.28	0.13	23.69	0.52	1927	151	2390	116	392	7
Center	0.1298	0.0035	222.13	5.72	8.75	0.23	20.92	0.35	1749	142	2543	102	387	7
Back	0.1391	0.0044	221.47	4.43	8.72	0.17	22.58	0.55	1795	98	2422	94	394	6
11931														
Front	0.1442	0.0045	206.93	13.56	8.15	0.53	24.61	0.86	1931	112	2220	91	403	8
Center	0.1294	0.0035	220.27	5.15	8.67	0.20	21.75	0.55	1823	129	2377	106	396	5
Back	0.1400	0.0039	216.77	4.31	8.53	0.17	24.41	0.77	1876	134	2171	93	398	7
11932														
Front	0.1444	0.0047	217.73	7.87	8.57	0.31	24.31	0.58	1967	83	2143	92	400	8
Center	0.1271	0.0035	212.87	7.78	8.38	0.31	21.12	0.36	1850	99	2294	118	402	7
Back	0.1362	0.0051	223.03	4.27	8.78	0.17	23.44	0.60	1886	109	2196	78	399	6
11933														
Front	0.1428	0.0053	210.67	5.11	8.29	0.20	23.68	0.67	1887	129	2120	111	399	8
Center	0.1225	0.0032	216.47	6.04	8.52	0.24	20.14	0.28	1876	119	2141	97	394	7
Back	0.1396	0.0046	219.50	4.77	8.68	0.18	22.44	0.57	1965	137	2069	80	399	7
11934														
Front	0.1403	0.0053	220.43	6.55	8.68	0.26	23.48	0.69	1988	149	2203	102	401	9
Center	0.1269	0.0032	228.43	4.91	8.99	0.19	20.44	0.37	1859	113	2352	120	398	7
Back	0.1357	0.0043	223.20	4.27	8.79	0.17	22.41	0.58	1914	115	2196	72	397	10

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST		IPST				T460		UM535				T538	
Sample ID (#)	ZD-Long. SEM (MN m/kg)	95% C.I.	Soft Caliper (microns)	95% C.I.	Soft Caliper (mills)	95% C.I.	Gurley Porosity (s/100ml)	95% C.I.	FS Bendtsen Roughness (ml/min)	95% C.I.	WS Bendtsen Roughness (ml/min)	95% C.I.	FS Sheffield Roughness (SU)	95% C.I.
11935														
Front	0.1407	0.0038	214.90	4.44	8.46	0.17	25.01	0.65	1844	101	2214	94	401	4
Center	0.1276	0.0035	221.13	4.29	8.71	0.17	20.87	0.34	1903	133	2419	104	397	11
Back	0.1349	0.0040	225.97	3.70	8.90	0.15	22.51	1.50	1923	108	2258	81	406	6
11936														
Front	0.1459	0.0043	209.40	4.67	8.24	0.18	24.05	0.60	1933	119	2154	94	399	8
Center	0.1310	0.0040	213.30	3.34	8.40	0.13	20.58	0.37	1717	88	2335	104	395	9
Back	0.1368	0.0039	213.47	4.46	8.40	0.18	22.27	0.59	1927	138	2220	103	404	8
11937														
Front									1587	140	1621	140		
Center									1252	117	1428	248		
Back									1298	137	1320	113		
11938														
Front									1666	138	1689	128		
Center									1462	173	1485	113		
Back									1655	203	1734	174		
11939														
Front									1723	146	1638	188		
Center									2131	137	2114	157		
Back									2420	87	2392	181		
11940														
Front									1581	138	1559	111		
Center									2177	78	2267	264		
Back									2488	264	2182	179		
11941														
Front									1990	133	1774	163		
Center									2375	143	2018	157		
Back									2449	165	2239	164		
11942														
Front	0.1031	0.0029	241.17	3.49	9.49	0.14	9.79	0.24	2307	67	2377	84	418	5
Center	0.0947	0.0024	245.93	4.39	9.68	0.17	8.83	0.16	2245	68	2315	90	412	6
Back	0.1060	0.0038	244.63	3.90	9.63	0.15	9.13	0.22	2366	78	2400	95	418	5

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST		IPST				T460		UM535				T538	
Sample ID (#)	ZD-Long. SEM (MN m/kg)	95% C.I.	Soft Caliper (microns)	95% C.I.	Soft Caliper (mills)	95% C.I.	Gurley Porosity (s/100ml)	95% C.I.	FS Bendtsen Roughness (ml/min)	95% C.I.	WS Bendtsen Roughness (ml/min)	95% C.I.	FS Sheffield Roughness (SU)	95% C.I.
11943														
Front	0.1004	0.0031	241.27	3.85	9.50	0.15	9.76	0.35	2381	85	2218	86	416	5
Center	0.0938	0.0028	239.47	2.86	9.43	0.11	8.63	0.24	2240	60	2224	75	412	6
Back	0.0975	0.0031	237.77	5.19	9.36	0.20	9.41	0.31	2345	67	2104	82	416	5
11944														
Front	0.1004	0.0036	244.13	4.25	9.61	0.17	9.63	0.38	2281	75	2326	108	412	5
Center	0.0885	0.0032	251.07	4.82	9.88	0.19	8.78	0.35	2282	64	2324	102	416	7
Back	0.0963	0.0032	248.10	4.25	9.77	0.17	9.09	0.35	2277	70	2239	99	415	4
11945														
Front	0.1067	0.0045	250.77	6.14	9.87	0.24	9.32	0.28	2343	101	2437	119	416	5
Center	0.0900	0.0032	254.87	3.97	10.03	0.16	8.53	0.25	2282	99	2368	121	415	5
Back	0.1005	0.0043	255.67	5.32	10.07	0.21	9.59	0.30	2368	75	2324	110	416	5
11946														
Front	0.0889	0.0025	244.65	4.13	9.63	0.16	10.71	0.23	1621	91	1604	54	378	6
Center	0.0756	0.0014	234.94	1.86	9.25	0.07	9.86	0.30	1536	39	1487	38	377	3
Back	0.0777	0.0018	235.30	1.74	9.26	0.07	12.24	0.30	1329	150	1238	113	350	10
11947														
Front	0.0889	0.0033	235.53	2.58	9.27	0.10	9.17	0.25	1908	89	1727	70	402	5
Center	0.0752	0.0022	240.10	2.24	9.45	0.09	8.39	0.20	1647	73	1602	64	395	4
Back	0.0859	0.0029	233.47	2.43	9.19	0.10	8.92	0.27	1704	59	1687	76	401	5
11948														
Front	0.0905	0.0025	238.45	3.08	9.39	0.12	10.60	0.31	1641	82	1669	105	379	6
Center	0.0775	0.0015	239.54	1.73	9.43	0.07	9.20	0.21	1658	46	1646	42	388	3
Back	0.0900	0.0023	239.30	6.76	9.42	0.27	10.14	0.25	1505	64	1508	70	377	5
11949														
Front	0.0873	0.0025	239.60	5.32	9.43	0.21	10.13	0.38	1479	92	1547	109	376	6
Center	0.0771	0.0015	239.89	1.82	9.44	0.07	9.10	0.23	1722	38	1648	44	389	3
Back	0.0895	0.0021	239.05	4.73	9.41	0.19	10.57	0.22	1593	70	1649	73	385	4
11950														
Front	0.1165	0.0031	224.90	3.51	8.85	0.14	16.26	0.49	1825	120	2296	98	396	8
Center	0.1117	0.0037	235.77	4.65	9.28	0.18	15.29	0.43	1903	103	2379	116	397	7
Back	0.1118	0.0033	229.97	5.24	9.05	0.21	14.71	0.52	1785	107	2277	87	396	7

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST		IPST				T460		UM535				T538	
Sample ID (#)	ZD-Long. SEM (MN m/kg)	95% C.I.	Soft Caliper (microns)	95% C.I.	Soft Caliper (mills)	95% C.I.	Gurley Porosity (s/100ml)	95% C.I.	FS Bendtsen Roughness (ml/min)	95% C.I.	WS Bendtsen Roughness (ml/min)	95% C.I.	FS Sheffield Roughness (SU)	95% C.I.
11951														
Front	0.1236	0.0032	219.07	3.92	8.62	0.15	15.59	0.20	1916	130	2194	94	397	11
Center	0.1163	0.0039	225.50	4.58	8.88	0.18	15.16	0.33	1886	119	2437	106	400	8
Back	0.1205	0.0037	217.27	3.58	8.55	0.14	14.95	0.27	1838	108	2328	95	395	10
11952														
Front	0.1300	0.0032	212.28	3.84	8.36	0.15	17.30	0.53	1868	96	2367	107	399	8
Center	0.1220	0.0031	216.40	3.51	8.52	0.14	16.20	0.42	1734	80	2347	81	396	6
Back	0.1245	0.0037	217.10	4.88	8.55	0.19	16.63	0.49	1817	95	2436	83	390	8
11953														
Front	0.1307	0.0033	215.20	4.47	8.47	0.18	19.55	0.61	1808	116	2358	98	403	9
Center	0.1206	0.0031	220.30	4.07	8.67	0.16	16.84	0.40	1746	106	2405	94	405	8
Back	0.1246	0.0033	218.88	5.36	8.62	0.21	18.30	0.56	1693	94	2238	89	396	7
11954														
Front	0.1327	0.0031	219.18	4.73	8.64	0.19	19.15	0.46	1853	113	2303	73	398	6
Center	0.1235	0.0035	221.15	3.86	8.71	0.15	16.12	0.41	1758	93	2385	103	401	10
Back	0.1311	0.0036	223.33	4.29	8.79	0.17	18.30	0.54	1944	111	2280	85	407	7
11955														
Front	0.1233	0.0041	226.07	5.81	8.90	0.23	17.17	0.61	1961	150	2284	92	407	8
Center	0.1065	0.0026	238.30	6.40	9.38	0.25	14.39	0.27	1859	130	2426	135	398	11
Back	0.1188	0.0047	235.00	6.02	9.25	0.24	16.62	0.54	1916	113	2269	93	397	10
11956														
Front	0.1287	0.0054	220.10	5.03	8.67	0.20	19.27	0.75	1872	146	2267	92	404	9
Center	0.1140	0.0029	229.43	7.15	9.03	0.28	15.86	0.28	1876	129	2282	108	393	11
Back	0.1235	0.0046	228.17	5.79	8.98	0.23	18.54	0.53	1982	144	2214	103	408	6

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST		IPST				T460		UM535				T538	
Sample ID (#)	ZD-Long. SEM (MN m/kg)	95% C.I.	Soft Caliper (microns)	95% C.I.	Soft Caliper (mills)	95% C.I.	Gurley Porosity (s/100ml)	95% C.I.	FS Bendtsen Roughness (ml/min)	95% C.I.	WS Bendtsen Roughness (ml/min)	95% C.I.	FS Sheffield Roughness (SU)	95% C.I.
Commercial Medium 107811														
Center	0.1397	0.0026	187.65	2.61	7.39	0.10	10.32	0.46	2792	97	2591	145		
Edge	0.1387	0.0019	190.08	2.59	7.48	0.10	10.97	0.40	2792	76	2588	84		
107812														
Center	0.1347	0.0034	180.95	2.90	7.12	0.11	11.76	0.74	2520	119	2681	89		
Edge	0.1342	0.0024	182.90	2.36	7.20	0.09	11.05	0.31	2651	83	2905	85		
107813														
Center	0.1500	0.0029	180.35	3.54	7.10	0.14	11.10	0.48	3024	96	2815	81		
Edge	0.1486	0.0024	180.05	2.08	7.09	0.08	11.80	0.37	3041	63	2778	77		
107814														
Center	0.1400	0.0027	188.95	3.39	7.44	0.13	10.50	0.52	2905	86	2650	109		
Edge	0.1385	0.0024	190.15	2.39	7.49	0.09	10.80	0.41	2915	51	2701	99		
107816														
Center	0.1487	0.0031	183.20	2.98	7.21	0.12	11.83	0.53	2792	153	2942	104		
Edge	0.1492	0.0024	186.10	2.17	7.33	0.09	11.85	0.34	2800	84	2885	84		
Commercial Liner 225111														
Center	0.1194	0.0066	209.25	5.34	8.24	0.21	15.63	0.59	1933	167	1817	128	394	8
Edge	0.1245	0.0033	208.58	1.89	8.21	0.07	15.57	0.50	2092	124	2211	168	393	5
225121														
Center	0.1034	0.0053	214.10	3.56	8.43	0.14	17.67	0.75	2182	267	2004	230	389	10
Edge	0.1118	0.0039	209.23	3.40	8.24	0.13	16.31	0.61	2327	163	2195	147	396	6

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							IPST							
Sample ID (#)	WS Sheffield Roughness (SU)	95% C.I.	FS Sheffield Roughness (ml/min)	95% C.I.	WS Sheffield Roughness (ml/min)	95% C.I.	CD FS Emveco Micro Dev.	95% C.I.	CD FS Emveco Micro Ave.	95% C.I.	MD FS Emveco Micro Dev.	95% C.I.	MD FS Emveco Micro Ave.	95% C.I.
11926														
Front	421	7	3365	55	3524	59	80.9	7.6	0.2246	0.0102	51.2	8.6	0.1764	0.0109
Center	420	5	3381	76	3515	40	82.4	5.3	0.2286	0.0075	58.7	8.9	0.1904	0.0130
Back	418	5	3373	57	3498	38	88.4	7.1	0.2348	0.0066	57.0	8.3	0.1874	0.0104
11927														
Front	401	8	3147	94	3356	66	73.6	5.5	0.2142	0.0092	49.4	10.4	0.1729	0.0171
Center	384	6	2930	80	3214	50	66.7	4.0	0.2034	0.0086	47.0	10.2	0.1684	0.0162
Back	376	6	3055	81	3147	50	66.2	3.8	0.2023	0.0065	45.8	7.6	0.1655	0.0128
11928														
Front	398	5	3164	62	3331	38	72.0	5.0	0.2097	0.0096	47.9	2.4	0.1711	0.0056
Center	383	6	2930	89	3206	49	69.5	4.5	0.2071	0.0062	46.6	5.4	0.1696	0.0093
Back	379	5	2980	70	3172	44	68.7	1.8	0.2067	0.0016	49.4	7.8	0.1731	0.0149
11930														
Front	417	5	3281	62	3490	40	85.7	6.7	0.2301	0.0103	53.3	6.7	0.1788	0.0089
Center	418	5	3239	57	3498	38	87.2	6.2	0.2332	0.0105	58.0	3.8	0.1905	0.0062
Back	417	5	3298	50	3490	40	93.0	20.2	0.2362	0.0146	53.5	4.7	0.1818	0.0072
11931														
Front	412	6	3373	69	3448	47	77.6	2.5	0.2213	0.0045	52.1	3.5	0.1823	0.0081
Center	420	5	3315	42	3515	40	82.5	4.7	0.2275	0.0037	55.5	4.8	0.1861	0.0106
Back	419	6	3331	55	3507	52	89.6	3.0	0.2375	0.0046	54.8	8.2	0.1809	0.0120
11932														
Front	409	7	3348	63	3423	59	79.8	3.7	0.2242	0.0051	54.4	7.2	0.1846	0.0145
Center	406	6	3365	55	3398	50	85.7	7.6	0.2305	0.0118	56.9	4.6	0.1876	0.0054
Back	409	4	3340	52	3423	34	87.9	8.2	0.2331	0.0107	53.4	8.8	0.1783	0.0187
11933														
Front	404	6	3340	66	3381	50	74.2	5.3	0.2150	0.0088	51.0	4.2	0.1741	0.0082
Center	412	7	3298	58	3448	62	81.5	4.1	0.2260	0.0057	53.3	4.3	0.1792	0.0071
Back	407	5	3340	59	3407	40	84.0	5.2	0.2286	0.0067	52.4	3.9	0.1781	0.0027
11934														
Front	411	4	3356	77	3440	34	78.5	4.1	0.2207	0.0037	52.2	5.5	0.1768	0.0084
Center	417	7	3331	62	3490	57	84.5	5.6	0.2279	0.0071	52.2	13.6	0.1793	0.0185
Back	407	7	3323	80	3407	57	84.2	11.2	0.2295	0.0137	52.6	5.2	0.1807	0.0139

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							IPST							
Sample ID (#)	WS Sheffield Roughness (SU)	95% C.I.	FS Sheffield Roughness (ml/min)	95% C.I.	WS Sheffield Roughness (ml/min)	95% C.I.	CD FS Emveco Micro Dev.	95% C.I.	CD FS Emveco Micro Ave.	95% C.I.	MD FS Emveco Micro Dev.	95% C.I.	MD FS Emveco Micro Ave.	95% C.I.
11935														
Front	410	7	3356	34	3432	56	78.1	3.3	0.2216	0.0035	56.5	6.2	0.1855	0.0087
Center	414	6	3323	89	3465	50	83.7	5.1	0.2289	0.0072	61.4	10.2	0.1916	0.0136
Back	413	6	3398	50	3457	49	83.7	2.8	0.2273	0.0042	56.4	6.2	0.1849	0.0099
11936														
Front	411	6	3340	66	3440	52	82.4	4.2	0.2266	0.0070	47.8	7.6	0.1712	0.0140
Center	409	4	3306	76	3423	34	80.0	7.9	0.2237	0.0108	54.4	5.1	0.1828	0.0109
Back	415	6	3381	64	3473	51	80.3	7.1	0.2246	0.0081	49.5	13.8	0.1739	0.0217
11937														
Front														
Center														
Back														
11938														
Front														
Center														
Back														
11939														
Front														
Center														
Back														
11940														
Front														
Center														
Back														
11941														
Front														
Center														
Back														
11942														
Front	412	5	3498	38	3448	38	179.2	7.4	0.3381	0.0066	133.6	16.8	0.2903	0.0150
Center	413	5	3448	47	3457	40	186.2	11.9	0.3404	0.0090	137.7	12.7	0.2954	0.0176
Back	412	5	3498	38	3448	38	184.3	8.7	0.3402	0.0068	155.3	18.0	0.3083	0.0109

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							IPST							
Sample ID (#)	WS Sheffield Roughness (SU)	95% C.I.	FS Sheffield Roughness (ml/min)	95% C.I.	WS Sheffield Roughness (ml/min)	95% C.I.	CD FS Emveco Micro Dev.	95% C.I.	CD FS Emveco Micro Ave.	95% C.I.	MD FS Emveco Micro Dev.	95% C.I.	MD FS Emveco Micro Ave.	95% C.I.
11943														
Front	415	6	3482	42	3473	51	178.2	8.9	0.3349	0.0073	136.1	13.2	0.2887	0.0173
Center	409	7	3448	47	3423	59	191.2	12.1	0.3475	0.0123	138.0	18.5	0.2934	0.0210
Back	411	4	3482	42	3440	34	181.1	5.1	0.3347	0.0034	139.0	14.2	0.2914	0.0100
11944														
Front	414	7	3448	38	3465	58	187.3	13.2	0.3412	0.0084	125.1	10.3	0.2806	0.0126
Center	412	6	3482	58	3448	47	182.5	6.6	0.3409	0.0098	135.9	19.1	0.2890	0.0214
Back	415	7	3473	32	3473	58	186.9	12.6	0.3421	0.0128	134.8	13.0	0.2883	0.0118
11945														
Front	412	6	3482	42	3448	47	188.5	10.4	0.3449	0.0095	136.1	13.3	0.2901	0.0094
Center	412	5	3473	42	3448	38	184.5	9.6	0.3399	0.0081	140.1	33.0	0.2922	0.0311
Back	417	7	3482	42	3490	57	175.7	19.3	0.3302	0.0156	140.7	16.3	0.2953	0.0149
11946														
Front	386	4	3164	47	3231	31	116.3	9.9	0.2692	0.0127	95.9	20.4	0.2394	0.0223
Center	371	2	3156	24	3103	20	104.9	8.5	0.2552	0.0122	82.3	18.4	0.2247	0.0208
Back	349	8	2930	80	2922	66	101.7	11.6	0.2503	0.0124	85.9	33.5	0.2278	0.0353
11947														
Front	397	7	3365	38	3323	57	147.9	7.6	0.3056	0.0075	112.4	16.4	0.2631	0.0174
Center	391	6	3306	32	3273	52	142.3	8.8	0.2957	0.0104	117.3	14.7	0.2713	0.0161
Back	389	6	3356	44	3256	52	135.0	8.7	0.2899	0.0100	110.5	7.5	0.2636	0.0103
11948														
Front	384	11	3172	52	3214	90	124.0	11.1	0.2762	0.0124	100.9	8.3	0.2467	0.0126
Center	382	2	3244	29	3199	20	120.7	8.4	0.2744	0.0095	108.6	17.0	0.2588	0.0260
Back	387	6	3156	40	3239	49	122.3	8.5	0.2758	0.0095	96.3	9.1	0.2458	0.0096
11949														
Front	381	7	3147	50	3189	59	125.6	5.8	0.2803	0.0078	104.6	9.9	0.2533	0.0143
Center	385	2	3253	27	3225	21	121.2	11.2	0.2755	0.0112	91.3	12.6	0.2340	0.0165
Back	383	6	3223	32	3206	49	113.4	8.5	0.2647	0.0122	103.5	8.7	0.2516	0.0083
11950														
Front	413	5	3315	64	3457	40	88.4	6.6	0.2355	0.0077	64.4	4.4	0.1987	0.0068
Center	419	7	3323	57	3507	59	87.7	5.5	0.2348	0.0053	60.6	8.0	0.1932	0.0111
Back	415	8	3315	58	3473	70	89.3	4.7	0.2360	0.0089	61.7	7.8	0.1939	0.0140

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							IPST							
Sample ID (#)	WS Sheffield Roughness (SU)	95% C.I.	FS Sheffield Roughness (ml/min)	95% C.I.	WS Sheffield Roughness (ml/min)	95% C.I.	CD FS Emveco Micro Dev.	95% C.I.	CD FS Emveco Micro Ave.	95% C.I.	MD FS Emveco Micro Dev.	95% C.I.	MD FS Emveco Micro Ave.	95% C.I.
11951														
Front	411	2	3323	89	3440	19	83.1	7.2	0.2268	0.0101	57.3	14.6	0.1887	0.0253
Center	410	8	3348	69	3432	63	82.8	10.2	0.2259	0.0141	59.9	8.4	0.1939	0.0173
Back	408	6	3306	86	3415	47	82.4	6.4	0.2261	0.0079	53.3	4.0	0.1819	0.0096
11952														
Front	416	6	3340	66	3482	50	78.8	3.6	0.2204	0.0047	50.4	4.1	0.1766	0.0065
Center	415	6	3315	50	3473	51	79.0	2.4	0.2221	0.0039	52.9	1.7	0.1812	0.0039
Back	413	6	3264	63	3457	49	78.5	4.0	0.2221	0.0065	51.3	1.6	0.1787	0.0027
11953														
Front	426	4	3373	75	3565	31	76.3	3.6	0.2174	0.0059	50.6	2.5	0.1751	0.0052
Center	426	5	3390	65	3565	42	81.2	2.3	0.2251	0.0026	57.0	5.1	0.1871	0.0077
Back	421	5	3315	58	3524	44	81.1	2.5	0.2249	0.0028	51.7	4.4	0.1778	0.0068
11954														
Front	422	7	3331	47	3532	55	71.9	2.7	0.2119	0.0044	47.5	2.3	0.1700	0.0055
Center	420	7	3356	82	3515	56	73.3	2.4	0.2137	0.0035	48.3	2.3	0.1722	0.0040
Back	418	6	3407	57	3498	47	74.4	3.0	0.2139	0.0046	46.1	3.1	0.1696	0.0072
11955														
Front	425	5	3407	69	3557	42	75.1	3.3	0.2152	0.0068	46.4	3.8	0.1663	0.0045
Center	417	8	3331	88	3490	63	74.0	5.8	0.2151	0.0076	50.6	8.0	0.1755	0.0111
Back	422	7	3323	85	3532	55	74.6	6.3	0.2159	0.0080	48.0	4.3	0.1709	0.0078
11956														
Front	417	8	3381	76	3490	63	74.0	5.5	0.2152	0.0077	45.7	10.0	0.1670	0.0196
Center	422	6	3289	89	3532	47	77.4	6.6	0.2194	0.0098	46.7	5.1	0.1681	0.0101
Back	422	8	3415	47	3532	68	82.7	9.0	0.2276	0.0100	45.0	6.6	0.1648	0.0115

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							IPST							
Sample ID (#)	WS Sheffield Roughness (SU)	95% C.I.	FS Sheffield Roughness (ml/min)	95% C.I.	WS Sheffield Roughness (ml/min)	95% C.I.	CD FS Emveco Micro Dev.	95% C.I.	CD FS Emveco Micro Ave.	95% C.I.	MD FS Emveco Micro Dev.	95% C.I.	MD FS Emveco Micro Ave.	95% C.I.
Commercial Medium														
107811														
Center														
Edge														
107812														
Center														
Edge														
107813														
Center														
Edge														
107814														
Center														
Edge														
107816														
Center														
Edge														
Commercial Liner														
225111														
Center	391	4	3294	65	3269	37	153.5	9.5	0.3056	0.0116	125.1	10.6	0.2733	0.0127
Edge	393	6	3285	44	3285	53	161.3	10.8	0.3130	0.0101	118.6	8.2	0.2650	0.0090
225121														
Center	391	7	3252	80	3269	60	200.6	50.6	0.3276	0.0259	124.0	12.9	0.2745	0.0140
Edge	398	5	3317	46	3329	40	213.6	35.1	0.3377	0.0184	134.7	14.7	0.2817	0.0120

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T527 (Diffuse)					T527 (Diffuse)				
	As Made					Conditioned and Exposed to Light 96 Hours				
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness
11926										
Front	13.96	0.06	56.95	6.42	24.07	13.06	0.13	55.09	7.36	22.83
Center	14.30	0.06	57.35	6.34	23.92	13.27	0.03	55.45	7.28	22.92
Back	14.06	0.14	57.04	6.33	23.98	13.01	0.06	55.15	7.21	23.08
11927										
Front	13.95	0.09	56.91	6.39	24.01	13.15	0.13	55.33	7.16	23.00
Center	14.19	0.08	57.20	6.35	23.92	13.29	0.05	55.49	7.09	23.06
Back	13.95	0.12	56.90	6.38	23.97	13.00	0.13	55.14	7.15	23.13
11928										
Front	14.04	0.11	57.02	6.45	24.00	13.19	0.29	55.38	7.23	22.91
Center	14.20	0.05	57.28	6.29	23.94	13.30	0.05	55.54	7.13	23.02
Back	14.04	0.05	56.98	6.38	23.90	13.06	0.11	55.17	7.27	22.96
11930										
Front	14.09	0.13	57.05	6.41	23.84	13.21	0.21	55.23	7.17	22.74
Center	14.28	0.11	57.29	6.39	23.89	13.18	0.05	55.23	7.16	22.81
Back	13.96	0.13	56.86	6.39	23.86	13.05	0.18	55.02	7.22	22.80
11931										
Front	14.20	0.11	57.23	6.34	23.92	13.38	0.10	55.51	7.12	22.76
Center	14.30	0.10	57.33	6.33	23.99	13.43	0.19	55.60	7.17	22.73
Back	13.98	0.08	56.92	6.34	23.97	13.27	0.08	55.29	7.30	22.63
11932										
Front	14.09	0.07	57.07	6.44	23.97	13.42	0.10	55.49	7.25	22.59
Center	14.15	0.04	57.16	6.33	23.95	13.38	0.05	55.47	7.10	22.68
Back	13.94	0.10	56.88	6.35	23.93	13.35	0.12	55.42	7.21	22.73
11933										
Front	14.13	0.16	57.07	6.31	23.81	13.45	0.11	55.44	7.13	22.52
Center	14.36	0.13	57.36	6.39	23.73	13.57	0.07	55.65	7.19	22.45
Back	14.14	0.07	56.99	6.44	23.74	13.44	0.12	55.53	6.99	22.59
11934										
Front	14.12	0.14	57.07	6.36	23.85	13.27	0.12	55.29	7.12	22.69
Center	14.47	0.08	57.48	6.22	23.70	13.48	0.06	55.61	7.09	22.64
Back	14.17	0.05	57.05	6.30	23.69	13.21	0.07	55.28	7.16	22.78

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T527 (Diffuse)					T527 (Diffuse)				
	As Made					Conditioned and Exposed to Light 96 Hours				
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness
11935										
Front	14.17	0.10	57.06	6.31	23.74	13.42	0.16	55.44	7.31	22.56
Center	14.37	0.08	57.33	6.37	23.68	13.73	0.12	55.86	7.08	22.40
Back	14.21	0.02	57.06	6.47	23.62	13.58	0.18	55.72	7.07	22.49
11936										
Front	14.13	0.19	56.96	6.47	23.64	13.56	0.14	55.73	7.49	21.43
Center	14.32	0.09	57.24	6.31	23.63	13.79	0.08	56.03	7.43	21.41
Back	14.09	0.07	56.90	6.32	23.67	13.56	0.13	55.66	7.50	21.36
11937										
Front										
Center										
Back										
11938										
Front										
Center										
Back										
11939										
Front										
Center										
Back										
11940										
Front										
Center										
Back										
11941										
Front										
Center										
Back										
11942										
Front	15.49	0.21	59.28	5.35	24.17	14.82	0.04	57.72	7.11	21.79
Center	15.67	0.13	59.41	5.77	24.10	14.99	0.08	57.89	7.06	21.74
Back	15.61	0.10	59.36	5.76	24.15	14.94	0.17	57.88	7.03	21.81

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T527 (Diffuse)					T527 (Diffuse)				
	As Made					Conditioned and Exposed to Light 96 Hours				
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness
11943										
Front	15.67	0.07	59.36	5.86	24.20	14.94	0.10	57.84	7.10	21.77
Center	15.75	0.09	59.47	5.77	24.17	14.95	0.10	57.81	7.22	21.67
Back	15.63	0.09	59.33	5.78	24.19	14.89	0.16	57.73	7.18	21.66
11944										
Front	15.65	0.09	59.35	5.80	24.07	14.94	0.07	57.85	7.16	21.75
Center	15.74	0.02	59.45	5.82	24.06	15.03	0.09	57.91	7.11	21.66
Back	15.72	0.14	59.43	5.80	24.04	14.92	0.15	57.76	7.19	21.58
11945										
Front	15.54	0.08	59.29	5.76	24.14	14.92	0.04	57.82	7.19	21.70
Center	15.80	0.07	59.45	5.85	23.91	15.04	0.04	57.93	7.11	21.67
Back	15.66	0.06	59.37	5.77	24.01	14.94	0.13	57.78	7.23	21.64
11946										
Front	15.49	0.24	59.00	6.17	23.80	14.93	0.25	57.79	6.87	21.74
Center	15.59	0.14	59.04	6.09	23.59	15.27	0.12	58.24	6.91	21.67
Back	15.37	0.26	58.74	6.13	23.67	14.98	0.28	57.88	6.97	21.81
11947										
Front	15.55	0.06	59.13	5.96	23.92	14.91	0.10	57.79	7.07	21.81
Center	15.68	0.05	59.32	5.79	23.97	15.02	0.12	57.90	7.08	21.71
Back	15.64	0.18	59.23	5.80	23.84	14.95	0.25	57.78	7.06	21.71
11948										
Front	15.59	0.13	59.12	5.72	23.87	15.12	0.27	58.03	7.04	21.73
Center	15.69	0.06	59.25	5.74	23.79	15.47	0.12	58.42	6.83	21.58
Back	15.56	0.18	59.08	5.67	23.87	15.08	0.40	57.96	6.92	21.73
11949										
Front	15.52	0.27	58.95	5.65	23.83	15.12	0.30	58.02	6.93	21.93
Center	15.68	0.11	59.19	5.83	23.68	15.47	0.14	58.46	6.76	21.65
Back	15.40	0.18	58.88	5.72	23.83	15.10	0.19	58.03	6.95	21.75
11950										
Front	13.65	0.09	56.44	6.43	24.23	13.05	0.09	55.16	7.58	21.77
Center	13.79	0.15	56.60	6.46	24.10	13.07	0.09	55.14	7.43	21.68
Back	13.59	0.21	56.30	6.60	24.06	12.99	0.14	55.00	7.59	21.67

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T527 (Diffuse)					T527 (Diffuse)				
	As Made					Conditioned and Exposed to Light 96 Hours				
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness
11951										
Front	13.43	0.10	56.09	6.55	24.05	12.99	0.14	55.01	7.64	21.64
Center	13.71	0.11	56.48	6.44	23.95	13.09	0.06	55.08	7.49	21.57
Back	13.56	0.15	56.18	6.63	23.94	12.90	0.14	54.83	7.59	21.62
11952										
Front	13.56	0.13	56.20	6.49	23.98	13.04	0.10	55.07	7.51	21.64
Center	13.72	0.08	56.39	6.50	23.76	13.10	0.07	55.06	7.54	21.51
Back	13.44	0.13	56.00	6.65	23.87	12.86	0.11	54.79	7.57	21.64
11953										
Front	13.46	0.09	56.00	6.57	23.81	12.82	0.12	54.61	7.48	21.35
Center	13.64	0.06	56.23	6.45	23.73	13.05	0.07	54.88	7.49	21.24
Back	13.41	0.09	55.83	6.61	23.73	12.83	0.15	54.56	7.56	21.30
11954										
Front	13.69	0.09	56.34	6.45	23.83	13.16	0.21	55.04	7.37	21.24
Center	14.13	0.04	56.83	6.34	23.58	13.47	0.05	55.50	7.16	21.30
Back	13.62	0.13	56.19	6.27	23.74	13.21	0.19	55.06	7.40	21.19
11955										
Front	13.89	0.15	56.54	6.32	23.73	13.32	0.19	55.28	7.24	21.27
Center	14.25	0.06	57.06	6.13	23.64	13.50	0.12	55.50	7.23	21.27
Back	13.84	0.08	56.47	6.23	23.68	13.36	0.14	55.26	7.30	21.19
11956										
Front	13.98	0.12	56.64	6.09	23.58	13.36	0.19	55.27	7.26	21.14
Center	14.26	0.12	56.99	6.11	23.55	13.48	0.06	55.43	7.16	21.18
Back	14.22	0.07	56.85	6.07	23.50	13.47	0.12	55.35	7.18	21.03

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T527 (Diffuse)					T527 (Diffuse)				
	As Made					Conditioned and Exposed to Light 96 Hours				
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness
Commercial Medium										
107811										
Center										
Edge										
107812										
Center										
Edge										
107813										
Center										
Edge										
107814										
Center										
Edge										
107816										
Center										
Edge										
Commercial Liner										
225111										
Center	16.03	0.07	58.63	6.47	21.96	15.97	0.05	58.83	6.56	21.14
Edge	16.01	0.06	58.62	6.49	21.97	15.91	0.04	58.75	6.51	21.13
225121										
Center	16.16	0.09	58.86	6.31	22.11	15.92	0.06	58.71	6.54	20.95
Edge	16.12	0.07	58.80	6.41	22.08	15.88	0.07	58.72	6.53	21.04

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T524 (Directional)					T480		T441				T403			
	Conditioned and Exposed to Light 96 Hours														
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Gloss	95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.	Burst (psi)	95% C.I.	Burst (kPa)	95% C.I.
11926															
Front	13.32	0.22	55.74	7.46	22.15	13.00	0.21	294.42	29.64	289.50	6.10	78.04	5.06	538.1	34.9
Center	13.59	0.26	56.17	7.32	22.14	12.52	0.35	304.54	5.67	293.92	12.36	76.84	3.34	529.8	23.0
Back	13.51	0.30	55.99	7.43	22.14	12.61	0.30	315.11	15.53	308.16	19.96	80.92	4.93	557.9	34.0
11927															
Front	13.48	0.34	56.00	7.42	22.22	13.09	0.40	293.53	5.26	292.28	10.70	79.00	5.46	544.7	37.6
Center	13.73	0.32	56.23	7.30	22.07	13.09	0.63	295.69	6.96	297.37	15.80	75.24	5.56	518.8	38.3
Back	13.44	0.42	55.92	7.37	22.21	13.26	0.57	292.20	5.98	295.33	4.78	75.92	5.19	523.4	35.8
11928															
Front	13.28	0.32	55.72	7.38	22.22	12.75	0.30	290.95	17.06	283.72	16.99	77.63	3.51	535.3	24.2
Center	13.60	0.21	56.18	7.28	22.26	12.96	0.38	295.82	12.28	300.51	5.93	76.14	7.17	525.0	49.4
Back	13.36	0.31	55.78	7.38	22.16	13.09	0.33	288.47	11.74	297.59	13.22	80.02	4.18	551.7	28.8
11930															
Front	13.40	0.26	55.75	7.37	22.00	12.04	0.32	296.85	11.34	297.17	9.71	78.19	3.65	539.1	25.2
Center	13.55	0.37	55.94	7.39	21.91	12.04	0.32	313.61	4.92	306.98	11.91	75.78	4.98	522.5	34.3
Back	13.46	0.33	55.77	7.23	21.91	11.98	0.35	294.27	9.79	301.32	14.32	79.70	3.21	549.6	22.1
11931															
Front	13.28	0.23	55.60	7.33	22.02	11.85	0.32	277.85	10.60	295.57	12.56	80.29	3.38	553.6	23.3
Center	13.46	0.39	55.91	7.37	22.08	12.16	0.28	291.66	25.32	299.68	19.98	76.04	5.52	524.3	38.1
Back	13.33	0.27	55.67	7.41	22.05	12.08	0.34	286.82	11.36	275.96	8.62	79.48	5.56	548.0	38.3
11932															
Front	13.47	0.29	55.84	7.26	21.94	12.20	0.33	277.48	17.98	271.92	11.88	78.64	4.17	542.2	28.7
Center	13.76	0.19	56.20	7.31	21.86	12.13	0.36	286.67	24.45	311.50	8.35	74.72	2.49	515.2	17.2
Back	13.61	0.32	56.03	7.22	21.93	12.07	0.23	300.98	7.15	313.66	11.10	79.05	4.00	545.0	27.6
11933															
Front	13.71	0.48	56.06	7.25	21.73	13.83	0.39	301.67	13.82	294.59	22.14	70.98	4.44	489.4	30.6
Center	13.75	0.18	56.18	7.15	21.85	13.67	0.35	300.93	6.70	296.33	5.91	74.72	5.95	515.2	41.0
Back	13.59	0.33	55.91	7.28	21.82	13.40	0.51	298.23	12.53	293.33	10.40	75.02	3.44	517.2	23.7
11934															
Front	13.54	0.37	55.95	7.27	21.88	14.13	0.30	308.40	5.81	294.39	21.11	74.90	5.10	516.4	35.1
Center	13.90	0.16	56.33	7.21	21.75	12.77	0.92	311.40	11.46	316.86	10.91	75.22	4.37	518.6	30.1
Back	13.67	0.46	56.09	7.25	21.90	13.25	0.41	304.79	19.43	317.01	12.64	75.58	5.04	521.1	34.8

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T524 (Directional)					T480		T441				T403			
	Conditioned and Exposed to Light 96 Hours														
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Gloss	95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.	Burst (psi)	95% C.I.	Burst (kPa)	95% C.I.
11935															
Front	13.75	0.46	56.18	7.16	21.85	13.60	0.55	292.84	11.55	287.24	13.19	79.68	5.03	549.4	34.7
Center	13.95	0.29	56.39	7.14	21.75	13.20	0.25	312.21	9.61	297.81	8.31	77.37	5.78	533.4	39.8
Back	13.57	0.32	55.96	7.24	21.90	12.93	0.35	297.83	9.03	301.15	9.47	76.98	4.64	530.7	32.0
11936															
Front	13.66	0.13	56.25	7.11	22.07	13.71	0.33	299.41	15.43	264.30	12.81	75.51	5.81	520.7	40.1
Center	14.08	0.31	56.75	7.01	22.02	13.33	0.32	290.07	21.57	280.70	12.67	74.77	5.13	515.5	35.3
Back	13.59	0.39	56.03	7.17	22.01	13.41	0.25	277.63	12.93	267.11	9.48	75.67	5.38	521.7	37.1
11937															
Front															
Center															
Back															
11938															
Front															
Center															
Back															
11939															
Front															
Center															
Back															
11940															
Front															
Center															
Back															
11941															
Front															
Center															
Back															
11942															
Front	14.94	0.42	58.16	6.81	22.40	7.07	0.12	372.22	15.77	361.84	15.00	70.20	3.82	484.0	26.4
Center	15.40	0.38	58.69	6.56	22.25	7.14	0.35	374.45	6.88	382.12	15.01	65.26	6.20	449.9	42.8
Back	15.26	0.20	58.56	6.61	22.35	8.10	0.44	372.02	3.89	355.06	8.69	66.16	4.69	456.2	32.4

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T524 (Directional)					T480		T441				T403			
	Conditioned and Exposed to Light 96 Hours														
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Gloss	95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.	Burst (psi)	95% C.I.	Burst (kPa)	95% C.I.
11943															
Front	15.24	0.35	58.54	6.76	22.36	7.07	0.13	318.95	10.52	315.31	12.53	67.87	4.74	468.0	32.7
Center	15.16	0.22	58.38	6.77	22.27	7.08	0.12	333.87	10.14	325.54	18.38	64.61	4.84	445.5	33.3
Back	15.29	0.34	58.52	6.79	22.21	7.32	0.12	325.59	9.34	321.63	10.88	66.41	2.31	457.9	15.9
11944															
Front	15.10	0.20	58.33	6.90	22.30	7.31	0.15	330.13	16.00	331.93	12.14	63.61	3.90	438.6	26.9
Center	15.41	0.27	58.68	6.75	22.21	7.26	0.17	341.96	3.89	339.23	12.17	71.05	4.75	489.9	32.8
Back	15.31	0.17	58.53	6.76	22.21	7.00	0.23	338.91	11.24	335.86	10.04	67.04	4.93	462.2	34.0
11945															
Front	15.03	0.37	58.28	6.81	22.40	7.15	0.13	329.79	14.18	327.87	24.65	64.97	4.16	447.9	28.7
Center	15.30	0.35	58.51	6.77	22.18	7.24	0.14	341.88	20.54	337.07	11.29	65.60	6.44	452.3	44.4
Back	15.02	0.42	58.17	6.83	22.22	7.21	0.14	336.99	14.37	321.31	14.64	67.92	6.44	468.3	44.4
11946															
Front	15.49	0.36	58.85	6.72	22.32	8.88	0.18	319.37	9.10	315.75	4.91	66.99	3.14	461.9	21.7
Center	16.09	0.47	59.49	6.65	22.33	9.36	0.23	323.69	10.39	314.72	12.54	65.51	4.59	451.7	31.6
Back	15.71	0.53	59.18	6.68	22.41	9.04	0.22	308.80	14.68	316.34	10.77	64.51	4.02	444.8	27.7
11947															
Front	15.26	0.23	58.62	6.90	22.46	7.48	0.15	354.27	14.71	373.08	12.52	65.53	5.09	451.8	35.1
Center	15.41	0.46	58.80	6.70	22.42	8.86	0.22	367.65	15.19	356.09	17.08	62.19	4.58	428.8	31.6
Back	15.21	0.33	58.65	6.82	22.41	7.58	0.39	357.12	23.07	365.61	9.73	65.03	3.47	448.4	23.9
11948															
Front	15.90	0.46	59.36	6.66	22.28	8.71	0.27	312.80	6.27	324.90	3.75	63.30	3.81	436.4	26.3
Center	16.06	0.20	59.49	6.53	22.13	9.22	0.43	313.54	9.51	308.99	8.47	61.83	5.42	426.3	37.4
Back	15.79	0.59	59.21	6.64	22.23	8.79	0.19	317.67	11.00	305.13	14.40	66.09	3.09	455.7	21.3
11949															
Front	15.99	0.36	59.49	6.52	22.29	8.86	0.17	311.45	13.02	314.65	23.14	64.54	4.35	445.0	30.0
Center	16.24	0.28	59.81	6.50	22.25	9.27	0.16	317.11	12.77	304.81	6.83	64.31	6.63	443.4	45.7
Back	15.84	0.43	59.34	6.60	22.34	9.06	0.25	309.73	6.83	290.07	13.65	64.45	4.42	444.4	30.4
11950															
Front	13.17	0.41	55.65	7.35	22.42	10.79	0.28	326.37	10.33	327.45	11.48	68.37	5.18	471.4	35.7
Center	13.19	0.45	55.56	7.22	22.20	10.84	0.28	335.79	20.55	336.48	7.32	70.35	4.12	485.1	28.4
Back	12.85	0.21	55.11	7.45	22.29	11.04	0.15	328.31	22.30	333.50	13.48	66.16	4.52	456.2	31.2

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T524 (Directional)					T480		T441				T403			
	Conditioned and Exposed to Light 96 Hours														
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Gloss	95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.	Burst (psi)	95% C.I.	Burst (kPa)	95% C.I.
11951															
Front	13.22	0.30	55.62	7.30	22.24	11.43	0.52	313.22	4.40	332.44	15.96	70.85	4.51	488.5	31.1
Center	13.27	0.21	55.61	7.17	22.09	11.68	0.24	326.91	7.64	313.25	19.55	68.12	4.36	469.7	30.1
Back	13.03	0.19	55.28	7.38	22.11	11.95	0.19	311.35	14.36	312.48	12.65	68.66	4.30	473.4	29.6
11952															
Front	12.99	0.17	55.24	7.39	22.14	12.47	0.44	297.98	16.32	302.09	9.28	68.25	3.13	470.6	21.6
Center	13.19	0.31	55.47	7.25	22.04	12.30	0.19	315.46	8.22	314.99	23.56	63.92	2.04	440.7	14.1
Back	12.87	0.35	55.10	7.44	22.22	12.66	0.33	306.51	12.78	312.02	9.82	71.16	6.69	490.7	46.1
11953															
Front	12.98	0.21	55.11	7.29	21.95	13.90	0.35	300.98	9.37	292.65	13.26	71.27	5.61	491.4	38.7
Center	13.20	0.41	55.43	7.18	21.97	13.19	0.29	322.78	19.62	314.82	9.37	69.86	5.75	481.7	39.7
Back	13.06	0.43	55.20	7.30	21.92	13.50	0.38	310.32	6.25	308.13	22.96	68.21	4.52	470.3	31.2
11954															
Front	13.11	0.51	55.34	7.11	21.99	15.53	0.29	302.06	20.66	298.32	17.98	73.24	4.85	505.0	33.4
Center	13.57	0.26	56.01	6.98	22.02	14.39	0.24	308.53	12.70	315.88	17.74	68.15	4.08	469.9	28.1
Back	13.20	0.25	55.43	7.19	21.93	14.98	0.35	305.92	13.21	321.14	9.66	70.82	4.68	488.3	32.3
11955															
Front	13.36	0.49	55.70	7.14	22.01	16.37	0.36	303.44	19.13	307.81	18.44	71.70	5.47	494.4	37.7
Center	13.45	0.27	55.81	7.10	21.96	15.33	0.43	310.76	8.83	319.29	12.90	71.32	5.08	491.8	35.0
Back	13.44	0.31	55.77	7.08	21.93	15.87	0.44	318.38	12.18	319.78	12.51	72.45	4.15	499.5	28.6
11956															
Front	13.24	0.42	55.48	7.10	21.92	17.63	0.34	285.32	9.77	294.66	11.02	74.18	5.31	511.5	36.6
Center	13.45	0.48	55.82	7.05	21.96	17.40	0.38	301.54	16.77	304.13	9.47	69.74	3.87	480.9	26.7
Back	13.39	0.19	55.66	7.02	21.86	17.36	0.36	293.95	12.78	301.77	12.40	72.63	3.61	500.8	24.9

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T524 (Directional)					T480		T441				T403			
	Conditioned and Exposed to Light 96 Hours														
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greeness	b* +Yellowness -Blueness	Gloss	95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.	Burst (psi)	95% C.I.	Burst (kPa)	95% C.I.
Commercial Medium 107811															
Center								203.07	10.61	210.30	4.28	35.58	1.20	245.3	8.3
Edge								211.67	6.14	212.28	7.71	35.34	1.18	243.7	8.2
107812															
Center								225.27	3.50	224.11	4.51	34.55	1.40	238.2	9.7
Edge								211.32	4.10	216.87	3.88	34.74	1.44	239.5	9.9
107813															
Center								196.02	12.52	197.27	14.01	34.46	2.66	237.6	18.3
Edge								206.70	6.82	208.90	12.62	35.73	1.51	246.3	10.4
107814															
Center								227.14	17.86	252.11	12.00	34.73	2.79	239.4	19.3
Edge								222.71	9.52	238.97	20.99	35.36	1.18	243.8	8.1
107816															
Center								242.75	27.03	230.50	12.79	35.47	1.26	244.5	8.7
Edge								262.33	14.59	234.36	16.88	35.33	1.76	243.6	12.2
Commercial Liner 225111															
Center	15.90	0.55	59.36	6.39	21.80	6.81	0.19	38.20	2.65	59.93	10.36	89.82	4.43	619.3	30.5
Edge	16.09	0.12	59.32	6.39	21.77	6.74	0.15	39.05	3.25	53.16	4.50	82.66	4.79	569.9	33.0
225121															
Center	15.92	0.19	58.95	6.18	21.51	6.84	0.14	41.79	8.36	61.45	10.79	85.02	4.89	586.2	33.7
Edge	15.83	0.35	59.06	6.22	21.60	6.56	0.21	44.25	4.54	65.14	4.25	79.44	3.11	547.8	21.5

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST				T826										T822	
Sample ID (#)	MD Crack Angle (deg)	95% C.I.	CD Crack Angle (deg)	95% C.I.	CD STFI (lbf/in)	95% C.I.	MD STFI (lbf/in)	95% C.I.	CD STFI Index (N*m/g)	95% C.I.	MD STFI Index (N*m/g)	95% C.I.	Geo Mean STFI Index (N*m/g)	95% C.I.	CD Ring Crush (lbf/in)	95% C.I.
11926																
Front	61.5	6.3	82.8	5.2	16.82	0.75	28.49	1.24	19.63	0.86	32.42	1.46	25.23	0.86	10.36	0.34
Center	59.8	2.9	65.7	7.7	15.86	0.50	27.19	0.82	18.79	0.60	32.51	1.05	24.70	0.59	10.06	0.19
Back	74.7	5.9	65.1	13.1	17.48	0.73	27.37	1.11	20.20	0.85	31.47	1.18	25.21	0.75	10.26	0.37
11927																
Front	57.0	3.8	60.4	5.5	17.03	0.57	28.91	1.19	19.94	0.66	34.19	1.41	26.11	0.76	10.70	0.53
Center	69.5	5.1	67.0	5.1	15.89	0.53	28.62	0.76	18.67	0.61	33.46	0.86	25.00	0.59	9.95	0.23
Back	67.2	3.1	70.1	10.3	16.39	0.69	27.75	0.71	19.11	0.83	33.26	0.87	25.21	0.67	10.20	0.58
11928																
Front	65.2	4.0	65.7	5.8	17.26	0.76	29.58	1.07	20.27	0.89	34.03	1.22	26.26	0.82	10.36	0.38
Center	73.3	3.3	72.3	5.2	16.19	0.65	29.39	0.76	18.84	0.74	34.07	0.89	25.33	0.67	9.86	0.24
Back	66.2	7.3	58.0	10.4	16.16	0.75	29.01	1.11	18.92	0.90	33.87	1.30	25.29	0.74	10.31	0.25
11930																
Front	70.4	4.9	76.2	10.4	17.53	0.78	30.11	1.17	19.86	0.89	34.29	1.32	26.09	0.83	10.60	0.28
Center	70.0	5.5	69.7	3.5	15.84	0.51	29.92	0.80	18.11	0.59	34.06	0.87	24.83	0.56	10.15	0.22
Back	69.0	4.6	70.4	3.8	17.03	0.48	29.42	0.97	19.85	0.60	33.21	1.06	25.67	0.56	10.83	0.35
11931																
Front	60.1	5.4	70.5	5.1	17.31	0.57	29.50	0.91	20.59	0.68	35.30	1.09	26.96	0.65	10.24	0.72
Center	59.7	7.7	63.2	4.9	16.09	0.66	29.75	0.80	18.95	0.76	34.76	0.89	25.66	0.68	10.01	0.24
Back	74.1	8.9	64.5	3.3	16.85	0.62	29.85	0.97	19.84	0.72	34.18	1.09	26.04	0.68	10.03	0.61
11932																
Front	72.1	3.1	68.4	9.8	16.97	0.58	29.74	0.96	20.04	0.67	35.34	1.14	26.61	0.68	10.33	0.52
Center	70.3	4.8	66.5	6.6	15.76	0.64	28.49	0.77	18.62	0.75	33.34	0.84	24.91	0.67	9.80	0.21
Back	73.2	7.0	73.9	6.4	16.48	0.52	27.56	1.12	19.49	0.62	31.77	1.06	24.89	0.55	10.13	0.43
11935																
Front	54.9	5.7	65.0	6.2	17.50	0.74	28.93	0.74	20.52	0.91	34.68	0.87	26.68	0.72	10.52	0.41
Center	56.4	3.5	73.2	4.7	15.35	0.53	28.28	0.79	18.17	0.63	33.89	0.91	24.82	0.61	9.75	0.28
Back	62.7	3.6	72.7	7.1	16.43	0.77	27.00	0.93	19.72	0.90	32.61	1.13	25.36	0.80	10.04	0.20
11934																
Front	64.8	4.8	64.4	6.9	17.23	0.52	29.65	0.95	20.19	0.60	34.52	1.10	26.40	0.63	10.40	0.46
Center	68.7	5.0	68.7	6.3	16.01	0.61	29.47	0.82	18.68	0.71	34.27	0.98	25.31	0.67	9.92	0.37
Back	74.4	5.2	74.8	8.2	16.92	0.61	28.31	1.06	19.66	0.70	32.95	1.27	25.45	0.72	10.23	0.36

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST				T826										T822	
Sample ID (#)	MD Crack Angle (deg)	95% C.I.	CD Crack Angle (deg)	95% C.I.	CD STFI (lbf/in)	95% C.I.	MD STFI (lbf/in)	95% C.I.	CD STFI Index (N*m/g)	95% C.I.	MD STFI Index (N*m/g)	95% C.I.	Geo Mean STFI Index (N*m/g)	95% C.I.	CD Ring Crush (lbf/in)	95% C.I.
11935																
Front	71.2	4.7	74.0	7.0	17.13	0.42	30.47	0.85	19.79	0.48	35.41	0.96	26.47	0.51	10.45	0.43
Center	71.9	5.5	68.1	7.2	16.05	0.35	29.99	0.74	18.61	0.42	34.41	0.88	25.30	0.45	10.40	0.23
Back	70.9	4.1	69.2	6.2	16.76	0.65	28.38	1.00	19.47	0.76	32.80	1.18	25.27	0.73	10.75	0.23
11936																
Front	71.2	5.6	73.2	10.8	17.60	0.80	30.65	0.99	20.66	0.96	35.22	1.16	26.98	0.81	10.40	0.35
Center	66.0	5.8	66.1	6.5	15.98	0.58	30.14	0.59	18.60	0.67	34.90	0.66	25.48	0.59	9.83	0.29
Back	72.2	5.4	68.0	8.2	17.03	0.77	29.71	1.06	19.79	0.87	34.42	1.17	26.10	0.80	10.49	0.36
11937																
Front																
Center																
Back																
11938																
Front																
Center																
Back																
11939																
Front																
Center																
Back																
11940																
Front																
Center																
Back																
11941																
Front																
Center																
Back																
11942																
Front	58.4	6.7	78.3	8.8	15.51	0.54	27.09	1.25	18.05	0.62	30.33	1.39	23.40	0.74	9.55	0.52
Center	65.3	6.3	84.9	9.8	14.24	0.52	27.04	0.72	16.50	0.60	31.25	0.80	22.71	0.57	8.93	0.24
Back	69.6	9.4	68.7	9.4	15.26	0.87	27.12	1.12	17.84	1.04	31.65	1.31	23.76	0.92	9.34	0.25

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST				T826										T822	
Sample ID (#)	MD Crack Angle (deg)	95% C.I.	CD Crack Angle (deg)	95% C.I.	CD STFI (lbf/in)	95% C.I.	MD STFI (lbf/in)	95% C.I.	CD STFI Index (N*m/g)	95% C.I.	MD STFI Index (N*m/g)	95% C.I.	Geo Mean STFI Index (N*m/g)	95% C.I.	CD Ring Crush (lbf/in)	95% C.I.
11943																
Front	60.8	5.2	68.9	5.9	16.09	0.49	27.44	0.90	19.11	0.57	32.13	1.10	24.78	0.60	9.53	0.39
Center	59.9	4.7	61.2	16.3	14.63	0.55	26.77	0.72	17.59	0.64	31.99	0.88	23.72	0.60	9.06	0.19
Back	68.6	4.4	69.1	5.0	15.64	0.87	25.95	0.96	18.63	1.01	30.41	1.05	23.80	0.82	9.36	0.22
11944																
Front	68.6	5.7	75.0	11.5	16.45	0.82	27.52	0.83	18.37	0.91	30.78	0.92	23.78	0.76	9.76	0.31
Center	62.4	6.0	61.7	9.2	15.09	0.45	27.13	0.77	17.25	0.52	30.89	0.87	23.08	0.52	9.11	0.22
Back	67.1	8.2	76.4	13.4	16.19	0.75	26.64	1.02	18.08	0.82	29.98	1.23	23.28	0.64	9.31	0.35
11945																
Front	66.6	2.8	46.1	12.3	15.64	0.81	26.68	0.85	17.54	0.90	29.73	1.02	22.83	0.76	9.85	0.47
Center	66.2	4.5	30.7	3.5	14.52	0.70	26.40	0.70	16.56	0.78	30.17	0.80	22.35	0.67	8.77	0.22
Back	67.3	5.5	65.8	14.8	15.63	0.65	26.96	0.98	17.51	0.74	30.36	1.13	23.05	0.69	9.60	0.58
11946																
Front	74.4	5.8	78.0	4.9	15.76	0.62	26.59	1.11	18.23	0.71	30.50	1.27	23.58	0.74	9.51	0.25
Center	68.8	5.2	72.4	8.1	14.85	0.55	27.16	0.75	17.47	0.59	31.93	0.86	23.61	0.54	8.75	0.24
Back	78.2	5.0	71.8	8.7	15.76	0.57	27.58	0.96	17.92	0.65	31.36	0.96	23.70	0.60	9.06	0.56
11947																
Front	56.1	9.8	75.8	9.5	15.43	0.59	26.39	1.08	17.89	0.69	30.71	1.26	23.44	0.69	9.44	0.49
Center	67.3	7.3	67.5	6.9	14.25	0.40	26.03	0.71	16.69	0.48	30.11	0.86	22.41	0.46	8.81	0.17
Back	70.0	6.0	67.2	10.0	14.75	0.49	26.64	0.91	17.40	0.60	30.46	1.21	23.02	0.51	9.05	0.47
11948																
Front	70.3	4.5	74.6	8.4	16.41	0.58	27.38	0.70	19.01	0.67	31.95	0.82	24.65	0.59	9.38	0.41
Center	67.3	2.8	72.2	6.5	14.31	0.42	26.98	0.57	16.91	0.49	31.52	0.65	23.09	0.46	8.45	0.20
Back	68.9	5.5	66.2	15.2	15.40	0.63	26.28	0.88	17.79	0.70	30.19	1.03	23.18	0.65	9.09	0.33
11949																
Front	66.6	6.8	65.5	7.9	14.99	0.69	25.23	0.87	17.52	0.80	29.14	1.00	22.59	0.70	9.09	0.40
Center	69.0	4.1	71.2	12.2	14.53	0.47	25.97	0.53	17.16	0.54	30.34	0.61	22.81	0.48	8.58	0.15
Back	71.5	7.0	68.3	10.0	15.08	0.62	26.54	1.01	17.66	0.76	30.31	1.15	23.13	0.70	9.06	0.88
11950																
Front	74.1	4.6	78.9	9.0	16.13	0.43	27.55	0.51	19.03	0.52	32.32	0.61	24.80	0.46	9.87	0.27
Center	73.4	10.8	76.8	8.8	15.81	0.57	27.71	0.75	18.34	0.64	32.23	0.90	24.31	0.61	9.38	0.20
Back	74.9	6.0	87.5	4.5	15.55	0.47	27.62	0.77	18.28	0.56	32.24	0.93	24.28	0.56	9.14	0.29

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST				T826										T822	
Sample ID (#)	MD Crack Angle (deg)	95% C.I.	CD Crack Angle (deg)	95% C.I.	CD STFI (lbf/in)	95% C.I.	MD STFI (lbf/in)	95% C.I.	CD STFI Index (N*m/g)	95% C.I.	MD STFI Index (N*m/g)	95% C.I.	Geo Mean STFI Index (N*m/g)	95% C.I.	CD Ring Crush (lbf/in)	95% C.I.
11951																
Front	65.4	9.0	68.5	9.4	16.75	0.60	29.03	0.66	19.52	0.69	34.02	0.84	25.77	0.60	9.75	0.41
Center	71.4	3.7	64.2	11.7	15.38	0.40	28.18	0.58	18.03	0.48	33.42	0.70	24.54	0.45	9.28	0.32
Back	68.8	7.5	68.6	12.6	16.09	0.57	28.03	0.64	18.73	0.67	32.78	0.75	24.78	0.59	9.58	0.31
11952																
Front					16.07	0.42	28.20	0.56	19.04	0.49	33.65	0.66	25.31	0.47	9.64	0.19
Center					15.03	0.51	27.79	0.58	18.07	0.61	33.17	0.76	24.49	0.55	9.25	0.15
Back	71.1	5.5	67.4	7.6	15.52	0.39	26.53	0.73	18.53	0.48	31.64	0.88	24.21	0.51	9.12	0.18
11953																
Front	77.4	3.8	89.4	5.8	16.65	0.44	28.42	0.69	18.91	0.53	33.25	0.84	25.07	0.46	9.63	0.15
Center	82.1	6.1	88.3	8.3	15.34	0.43	27.56	0.55	17.82	0.49	32.30	0.69	23.98	0.45	9.16	0.14
Back	79.3	6.9	73.3	5.9	15.28	0.61	26.66	0.60	18.13	0.73	31.06	0.72	23.73	0.63	9.40	0.14
11954																
Front	74.4	5.0	70.0	5.2	16.81	0.43	28.65	0.62	19.43	0.49	33.26	0.70	25.42	0.46	10.11	0.19
Center	73.1	4.3	79.7	4.8	15.86	0.52	28.17	0.53	18.28	0.59	32.81	0.65	24.49	0.52	9.68	0.13
Back	69.8	1.5	76.4	7.3	16.35	0.60	28.00	0.67	18.76	0.68	32.59	0.78	24.73	0.62	9.75	0.13
11955																
Front	70.8	5.8	67.0	5.3	16.65	0.57	28.90	0.90	19.27	0.65	33.37	1.03	25.36	0.65	9.55	0.28
Center	70.9	8.7	76.0	6.9	15.59	0.62	28.38	0.78	17.95	0.71	32.59	0.92	24.18	0.66	9.32	0.21
Back	80.4	6.2	74.5	7.4	16.76	0.59	27.53	0.87	19.07	0.67	31.53	1.01	24.52	0.66	9.41	0.27
11956																
Front	79.6	6.1	75.5	7.6	16.44	0.61	29.96	0.80	19.08	0.72	34.07	0.92	25.49	0.66	8.82	0.25
Center	74.1	6.8	79.7	6.8	15.63	0.60	28.98	0.66	18.15	0.74	34.43	0.79	24.99	0.59	8.55	0.18
Back	78.3	8.1	86.3	6.3	15.89	0.48	27.31	0.62	18.58	0.56	32.02	0.69	24.39	0.52	8.80	0.26

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	IPST				T826										T822	
Sample ID (#)	MD Crack Angle (deg)	95% C.I.	CD Crack Angle (deg)	95% C.I.	CD STFI (lbf/in)	95% C.I.	MD STFI (lbf/in)	95% C.I.	CD STFI Index (N*m/g)	95% C.I.	MD STFI Index (N*m/g)	95% C.I.	Geo Mean STFI Index (N*m/g)	95% C.I.	CD Ring Crush (lbf/in)	95% C.I.
Commercial Medium																
107811																
Center					11.69	0.43	21.35	0.60	17.33	0.60	32.14	0.85	23.60	0.57	5.17	0.19
Edge					10.75	0.25	21.29	0.79	16.18	0.38	31.31	1.07	22.50	0.51	5.37	0.15
107812																
Center					10.77	0.61	20.19	0.64	16.33	0.90	30.74	0.98	22.39	0.76	5.13	0.33
Edge					11.03	0.23	19.93	0.34	16.93	0.32	30.85	0.42	22.85	0.29	5.05	0.21
107813																
Center					10.35	0.44	20.00	0.51	16.02	0.66	31.10	0.79	22.32	0.56	4.53	0.28
Edge					10.91	0.22	20.70	0.40	16.65	0.33	31.60	0.62	22.94	0.36	4.83	0.21
107814																
Center					11.14	0.29	21.99	0.49	16.86	0.44	31.66	0.69	23.10	0.41	5.35	0.28
Edge					10.97	0.23	20.24	0.57	16.39	0.34	30.35	0.73	22.29	0.32	5.12	0.16
107816																
Center					10.57	0.26	20.58	0.53	16.56	0.37	31.29	0.83	22.76	0.42	4.86	0.35
Edge					11.09	0.21	21.47	0.46	16.64	0.29	32.28	0.63	23.17	0.30	4.97	0.15
Commercial Liner																
225111																
Center	67.1	4.2	85.4	8.9	17.83	0.69	31.04	0.72	21.33	0.82	37.06	0.90	28.12	0.70	10.51	0.45
Edge	71.8	3.6	83.7	3.4	17.91	0.48	33.80	0.77	21.71	0.56	40.30	0.88	29.58	0.54	9.90	0.41
225121																
Center	77.8	3.6	89.5	7.2	17.97	0.81	32.27	1.18	21.23	0.98	38.31	1.36	28.51	0.90	10.57	0.45
Edge	70.3	3.6	81.2	5.5	18.20	0.50	33.65	0.63	21.75	0.62	40.48	0.73	29.67	0.56	10.42	0.42

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							T494							
Sample ID (#)	MD Ring Crush (lbf/in)	95% C.I.	CD R. C. Index (N*m/g)	95% C.I.	MD R. C. Index (N*m/g)	95% C.I.	CD Tensile (lbf/in)	95% C.I.	MD Tensile (lbf/in)	95% C.I.	CD Tensile Index (N*m/g)	95% C.I.	MD Tensile Index (N*m/g)	95% C.I.
11926														
Front	14.82	1.36	12.02	0.34	17.01	1.59	28.15	0.78	67.01	3.50	32.48	0.92	77.57	4.22
Center	14.66	0.28	11.85	0.19	17.43	0.36	24.50	0.85	69.03	1.40	28.88	0.96	81.52	1.51
Back	14.11	1.10	11.79	0.38	16.23	1.28	27.71	0.39	66.94	1.06	32.37	0.40	78.21	1.30
11927														
Front	15.14	0.42	12.50	0.59	17.87	0.41	28.00	0.70	67.99	1.38	33.06	0.80	78.97	1.37
Center	14.81	0.18	11.61	0.27	17.33	0.25	25.08	0.53	68.84	1.58	29.37	0.55	80.81	1.83
Back	14.46	0.34	11.93	0.62	16.91	0.44	27.79	0.60	64.82	2.34	32.73	0.70	76.08	2.66
11928														
Front	15.09	0.34	12.06	0.40	17.47	0.35	28.04	0.50	67.79	3.14	32.65	0.59	78.49	3.49
Center	14.39	0.27	11.44	0.23	16.73	0.30	25.50	0.36	68.80	1.81	29.50	0.43	79.68	2.06
Back	14.58	0.35	11.97	0.31	16.96	0.35	28.05	0.52	64.70	2.02	32.44	0.65	75.16	1.98
11930														
Front	14.52	0.91	12.08	0.36	16.76	1.04	28.44	0.60	67.55	2.58	32.59	0.62	77.68	2.98
Center	15.11	0.25	11.63	0.25	17.43	0.27	25.30	0.67	68.78	2.68	29.18	0.79	79.10	3.45
Back	15.24	0.44	12.44	0.43	17.53	0.52	28.19	1.02	66.09	1.44	32.42	1.14	75.55	1.51
11931														
Front	14.81	0.43	12.04	0.88	17.47	0.46	27.37	0.58	65.40	2.07	32.27	0.61	77.32	2.78
Center	14.42	0.22	11.74	0.28	16.93	0.29	25.53	0.29	70.81	0.87	30.00	0.54	83.48	1.10
Back	14.51	0.41	11.63	0.66	17.12	0.45	28.03	0.69	66.00	1.01	33.15	0.80	78.13	1.11
11932														
Front	14.95	0.41	12.29	0.55	17.67	0.38	27.32	0.75	68.73	1.16	32.46	0.92	81.37	1.62
Center	14.26	0.37	11.61	0.23	16.92	0.44	24.76	0.40	70.24	1.15	29.44	0.45	83.33	1.02
Back	14.60	0.34	12.01	0.54	17.22	0.45	28.29	0.61	65.90	2.07	33.65	0.68	78.54	1.76
11933														
Front	15.00	0.46	12.38	0.43	17.69	0.49	27.07	0.60	66.71	1.86	32.29	0.73	79.44	2.19
Center	14.16	0.41	11.58	0.34	17.03	0.47	24.06	0.33	67.54	1.25	28.55	0.50	80.74	1.59
Back	14.65	0.37	11.81	0.23	17.40	0.34	27.56	0.53	65.35	3.09	32.47	0.59	78.07	3.36
11934														
Front	14.71	1.07	12.10	0.54	17.17	1.20	28.50	0.86	69.32	1.81	32.45	0.91	80.09	1.88
Center	14.63	0.30	11.49	0.38	17.15	0.36	24.41	0.55	69.94	1.48	28.68	0.57	81.71	1.84
Back	14.81	0.40	11.89	0.36	17.21	0.52	28.14	0.89	66.79	2.08	32.80	0.93	77.06	1.59

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							T494							
Sample ID (#)	MD Ring Crush (lbf/in)	95% C.I.	CD R. C. Index (N*m/g)	95% C.I.	MD R. C. Index (N*m/g)	95% C.I.	CD Tensile (lbf/in)	95% C.I.	MD Tensile (lbf/in)	95% C.I.	CD Tensile Index (N*m/g)	95% C.I.	MD Tensile Index (N*m/g)	95% C.I.
11935														
Front	15.43	0.55	12.05	0.52	17.81	0.62	27.79	0.52	68.10	2.26	32.15	0.66	79.09	2.61
Center	14.97	0.33	11.93	0.24	17.24	0.38	25.65	0.47	71.47	0.85	29.58	0.52	82.50	1.04
Back	15.05	0.53	12.39	0.27	17.20	0.67	28.54	0.50	66.87	1.83	32.92	0.66	76.57	1.77
11936														
Front	14.37	0.36	12.12	0.43	16.77	0.41	26.84	0.97	68.10	2.62	31.41	1.11	79.19	2.98
Center	14.57	0.26	11.57	0.30	17.14	0.28	24.99	0.63	69.33	1.69	29.27	0.74	80.97	1.58
Back	15.07	0.55	12.04	0.38	17.53	0.62	27.50	0.68	67.43	1.52	32.07	0.76	78.80	1.15
11937														
Front														
Center														
Back														
11938														
Front														
Center														
Back														
11939														
Front														
Center														
Back														
11940														
Front														
Center														
Back														
11941														
Front														
Center														
Back														
11942														
Front	12.70	0.43	10.85	0.57	14.63	0.60	24.46	0.75	59.62	2.15	27.93	0.90	67.51	2.57
Center	13.03	0.29	10.41	0.27	15.07	0.33	22.88	0.36	61.41	1.56	26.21	0.32	70.21	2.12
Back	13.33	0.46	10.86	0.31	15.43	0.51	23.91	0.74	57.87	2.13	27.77	1.01	66.51	1.98

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							T494							
Sample ID (#)	MD Ring Crush (lbf/in)	95% C.I.	CD R. C. Index (N*m/g)	95% C.I.	MD R. C. Index (N*m/g)	95% C.I.	CD Tensile (lbf/in)	95% C.I.	MD Tensile (lbf/in)	95% C.I.	CD Tensile Index (N*m/g)	95% C.I.	MD Tensile Index (N*m/g)	95% C.I.
11943														
Front	13.35	0.29	11.34	0.45	15.85	0.32	23.95	0.57	55.75	2.82	28.01	0.57	65.00	3.13
Center	12.88	0.28	10.72	0.22	15.26	0.33	21.91	0.39	58.62	1.53	26.18	0.48	69.94	1.69
Back	13.53	0.26	11.03	0.30	15.91	0.28	24.72	0.54	56.97	2.08	29.22	0.71	66.99	2.45
11944														
Front	13.61	0.32	11.05	0.30	15.23	0.44	24.01	0.81	59.38	2.18	27.19	0.85	67.01	2.45
Center	13.00	0.20	10.39	0.24	14.86	0.22	23.27	0.40	62.42	1.14	26.43	0.34	70.17	1.46
Back	13.18	0.26	10.47	0.36	15.05	0.30	25.32	0.28	59.63	1.37	28.62	0.37	67.00	1.50
11945														
Front	13.58	0.29	11.07	0.54	15.41	0.37	23.89	0.53	58.77	2.81	27.38	0.55	66.79	3.05
Center	13.06	0.27	10.02	0.23	14.92	0.30	22.77	0.55	60.28	1.37	25.95	0.62	68.20	1.75
Back	13.37	0.59	10.88	0.58	15.27	0.68	24.24	0.64	57.81	1.79	27.87	0.74	66.08	1.70
11946														
Front	13.46	0.26	10.95	0.31	15.43	0.24	24.90	0.45	57.02	1.91	28.54	0.55	65.99	1.99
Center	12.60	0.40	10.34	0.24	14.85	0.38	22.88	0.47	60.22	1.08	26.27	0.50	69.41	0.92
Back	12.77	0.55	10.39	0.67	14.38	0.54	23.46	0.64	59.08	2.91	26.96	0.79	68.26	3.21
11947														
Front	13.45	0.38	10.93	0.59	15.65	0.32	23.99	0.58	58.21	2.59	28.11	0.76	68.09	2.82
Center	13.01	0.29	10.25	0.20	15.18	0.34	22.51	0.48	59.03	1.48	26.23	0.46	68.58	1.80
Back	12.57	0.82	10.62	0.54	14.75	0.95	23.47	0.76	55.90	2.00	27.57	0.82	65.89	2.24
11948														
Front	13.55	0.43	11.00	0.51	15.68	0.61	24.18	0.60	57.40	2.07	28.26	0.65	67.04	2.34
Center	12.51	0.42	9.89	0.24	14.71	0.47	22.04	0.50	59.65	1.76	25.65	0.41	69.58	2.08
Back	12.55	0.30	10.53	0.34	14.69	0.44	23.93	0.68	56.81	2.31	27.67	0.79	66.37	2.36
11949														
Front	12.88	0.54	10.36	0.43	14.72	0.54	23.36	0.91	57.33	1.80	26.95	1.13	66.10	2.41
Center	12.23	0.18	10.04	0.18	14.26	0.21	22.01	0.29	59.02	1.71	25.63	0.39	68.80	1.89
Back	13.33	0.42	10.54	1.02	15.43	0.43	23.93	0.33	58.02	1.85	27.54	0.33	66.83	2.20
11950														
Front	13.35	0.61	11.59	0.29	15.61	0.71	25.12	0.54	58.15	7.85	29.66	0.70	68.45	9.30
Center	13.24	0.45	10.95	0.25	15.39	0.59	23.53	0.80	63.86	0.80	27.38	0.83	74.32	1.29
Back	12.92	0.52	10.72	0.33	15.13	0.59	25.48	0.36	60.67	1.49	29.90	0.40	71.36	1.56

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							T494							
Sample ID (#)	MD Ring Crush (lbf/in)	95% C.I.	CD R. C. Index (N*m/g)	95% C.I.	MD R. C. Index (N*m/g)	95% C.I.	CD Tensile (lbf/in)	95% C.I.	MD Tensile (lbf/in)	95% C.I.	CD Tensile Index (N*m/g)	95% C.I.	MD Tensile Index (N*m/g)	95% C.I.
11951														
Front	13.18	0.47	11.42	0.47	15.43	0.54	25.91	0.47	60.55	1.81	30.14	0.64	70.94	2.27
Center	13.14	0.51	10.88	0.35	15.40	0.60	23.34	0.69	64.18	0.99	27.43	0.75	74.89	1.36
Back	13.23	0.41	11.27	0.35	15.43	0.50	25.83	0.45	60.02	1.90	30.46	0.48	70.25	1.90
11952														
Front	13.15	0.27	11.46	0.20	15.62	0.29	25.33	0.78	62.85	2.10	30.06	0.91	75.09	2.23
Center	13.02	0.24	11.01	0.16	15.47	0.26	23.43	0.38	63.63	1.22	27.72	0.50	75.64	1.55
Back	12.66	0.25	10.88	0.19	15.12	0.30	25.21	0.65	59.78	1.35	29.94	0.73	71.06	1.80
11953														
Front	13.49	0.21	11.32	0.16	15.87	0.23	25.60	0.83	63.43	1.99	30.16	0.80	75.31	1.98
Center	13.29	0.15	10.75	0.14	15.51	0.17	23.77	0.53	62.62	1.69	27.89	0.64	74.46	2.09
Back	13.09	0.17	11.04	0.16	15.53	0.20	25.48	0.70	60.21	1.34	30.43	0.66	71.84	1.68
11954														
Front	13.77	0.18	11.63	0.22	15.93	0.20	26.14	0.66	65.49	2.08	30.23	0.73	75.83	2.49
Center	13.56	0.18	11.16	0.15	15.63	0.20	23.95	0.44	66.21	1.61	27.87	0.49	76.56	1.57
Back	13.40	0.22	11.22	0.15	15.54	0.22	26.74	0.62	59.96	1.76	31.09	0.60	69.83	2.37
11955														
Front	12.57	0.26	10.98	0.31	14.54	0.27	26.33	0.73	63.04	2.42	30.38	0.93	72.97	2.89
Center	12.73	0.30	10.65	0.21	14.64	0.31	23.98	0.26	65.65	1.00	27.68	0.39	75.86	1.34
Back	12.75	0.32	10.78	0.31	14.67	0.32	26.77	0.58	62.74	1.04	30.65	0.62	72.10	1.41
11956														
Front	12.16	0.24	10.14	0.26	13.96	0.25	26.26	0.62	65.02	2.78	30.61	0.73	75.51	2.93
Center	11.97	0.28	9.94	0.19	13.82	0.29	24.63	0.61	64.11	2.33	29.03	0.66	74.89	2.61
Back	12.05	0.33	10.25	0.30	13.99	0.40	26.81	0.48	63.10	1.62	31.45	0.58	73.46	1.55

Table E3 cont. Average Physical Property Data by Lane.

Test Methods							T494							
Sample ID (#)	MD Ring Crush (lbf/in)	95% C.I.	CD R. C. Index (N*m/g)	95% C.I.	MD R. C. Index (N*m/g)	95% C.I.	CD Tensile (lbf/in)	95% C.I.	MD Tensile (lbf/in)	95% C.I.	CD Tensile Index (N*m/g)	95% C.I.	MD Tensile Index (N*m/g)	95% C.I.
Commercial Medium														
107811														
Center	7.33	0.28	7.87	0.24	11.26	0.40	12.63	0.36	38.01	1.13	19.04	0.49	57.02	1.17
Edge	8.21	0.21	8.02	0.20	12.04	0.29	12.34	0.25	36.60	0.79	18.81	0.32	55.13	1.14
107812														
Center	6.97	0.38	7.87	0.46	10.68	0.57	12.57	0.26	35.57	0.95	19.27	0.41	54.61	1.22
Edge	7.35	0.21	7.73	0.30	11.13	0.28	12.96	0.17	36.10	1.00	19.66	0.23	54.84	1.44
107813														
Center	7.07	0.20	7.14	0.43	10.84	0.26	11.85	0.32	34.88	2.51	18.32	0.48	53.92	2.97
Edge	7.55	0.13	7.41	0.26	11.46	0.17	12.11	0.26	34.71	1.08	18.56	0.40	52.93	1.52
107814														
Center	8.14	0.29	8.05	0.41	12.09	0.41	12.46	0.42	38.23	1.67	18.77	0.59	57.80	1.60
Edge	7.88	0.18	7.73	0.19	11.82	0.24	12.41	0.22	37.51	0.98	18.80	0.35	56.59	1.06
107816														
Center	7.63	0.27	7.55	0.45	11.55	0.37	12.61	0.36	36.36	1.55	19.28	0.51	55.44	1.92
Edge	7.72	0.25	7.63	0.20	11.70	0.30	12.44	0.25	35.84	1.17	18.87	0.37	54.69	1.62
Commercial Liner														
225111														
Center	14.52	0.65	12.30	0.54	17.03	0.68	27.01	1.40	75.94	3.36	33.03	1.64	93.23	3.95
Edge	14.13	0.43	11.68	0.39	16.86	0.36	26.98	0.58	75.44	3.08	32.56	0.80	90.38	2.95
225121														
Center	14.41	0.50	12.38	0.55	16.80	0.57	24.81	1.40	73.20	2.87	29.13	1.77	85.37	4.32
Edge	14.35	0.29	12.13	0.49	16.83	0.33	26.60	0.75	77.34	1.62	31.72	0.95	90.66	2.12

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T494								IPST		IPST		T809			
Sample ID (#)	CD Young's Modulus (lbf/in^2)	95% C.I.	MD Young's Modulus (lbf/in^2)	95% C.I.	CD Young's Modulus (MN/m^2)	95% C.I.	MD Young's Modulus (MN/m^2)	95% C.I.	OD Basis Weight (g/m^2)	95% C.I.	OD Density (g/cm^3)	95% C.I.	Concora (lbf)	95% C.I.	Concora (N)	95% C.I.
11926																
Front	22602	481	57384	2057	155.8	3.3	395.6	14.2	151.69	0.71	0.702	0.018				
Center	20356	418	57241	1948	140.3	2.9	394.6	13.4	148.03	0.51	0.682	0.013				
Back	21819	806	54920	1172	150.4	5.6	378.6	8.1	151.20	0.63	0.700	0.021				
11927																
Front	21474	385	56306	1780	148.0	2.7	388.2	12.3	149.29	0.76	0.732	0.010				
Center	20171	669	57194	935	139.1	4.6	394.3	6.4	149.66	0.44	0.726	0.009				
Back	21347	808	53035	1217	147.2	5.6	365.6	8.4	149.21	0.59	0.725	0.012				
11928																
Front	21905	555	57128	2456	151.0	3.8	393.9	16.9	150.82	0.68	0.715	0.016				
Center	19738	493	57001	1075	136.1	3.4	393.0	7.4	150.94	0.51	0.720	0.008				
Back	21246	605	54431	820	146.5	4.2	375.3	5.7	150.81	0.65	0.708	0.016				
11930																
Front	22043	760	55948	1087	152.0	5.2	385.7	7.5	152.77	0.75	0.728	0.015				
Center	20489	612	50291	9610	141.3	4.2	346.7	66.3	152.37	0.46	0.686	0.020				
Back	21726	459	53774	1800	149.8	3.2	370.7	12.4	152.53	0.73	0.686	0.020				
11931																
Front	21169	911	54476	2266	145.9	6.3	375.6	15.6	148.39	0.57	0.706	0.020				
Center	19308	414	54621	1813	133.1	2.9	376.6	12.5	149.13	0.50	0.678	0.015				
Back	20908	497	53512	2255	144.1	3.4	368.9	15.5	149.03	0.79	0.684	0.018				
11932																
Front	20364	1200	54598	2184	140.4	8.3	376.4	15.1	147.68	0.63	0.671	0.029				
Center	19989	268	55070	1461	137.8	1.8	379.7	10.1	147.75	0.55	0.694	0.030				
Back	20710	544	51956	1875	142.8	3.8	358.2	12.9	147.81	0.92	0.667	0.021				
11933																
Front									147.76	0.60	0.692	0.024				
Center	20229	407	56758	971	139.5	2.8	391.3	6.7	146.75	0.56	0.679	0.018				
Back	21234	812	55725	1305	146.4	5.6	384.2	9.0	147.67	0.75	0.686	0.020				
11934																
Front	21585	634	55785	1834	148.8	4.4	384.6	12.6	151.35	0.73	0.686	0.022				
Center	20007	626	54425	1713	137.9	4.3	375.2	11.8	150.05	0.55	0.657	0.016				
Back	18066	1464	53884	2271	124.6	10.1	371.5	15.7	150.83	0.78	0.679	0.019				

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T494								IPST		IPST		T809			
Sample ID (#)	CD Young's Modulus (lbf/in^2)	95% C.I.	MD Young's Modulus (lbf/in^2)	95% C.I.	CD Young's Modulus (MN/m^2)	95% C.I.	MD Young's Modulus (MN/m^2)	95% C.I.	OD Basis Weight (g/m^2)	95% C.I.	OD Density (g/cm^3)	95% C.I.	Concora (lbf)	95% C.I.	Concora (N)	95% C.I.
11935																
Front	21469	413	51977	907	148.0	2.8	358.3	6.3	151.43	0.69	0.720	0.016				
Center	19901	313	53006	1075	137.2	2.2	365.4	7.4	152.13	0.48	0.688	0.015				
Back	20772	321	50376	1253	143.2	2.2	347.3	8.6	152.37	0.65	0.678	0.015				
11936																
Front	21453	392	51957	1440	147.9	2.7	358.2	9.9	150.20	0.67	0.710	0.023				
Center	19720	347	53156	889	136.0	2.4	366.5	6.1	149.29	0.48	0.700	0.011				
Back	20729	434	52115	838	142.9	3.0	359.3	5.8	150.76	0.70	0.696	0.019				
11937																
Front																
Center																
Back																
11938																
Front																
Center																
Back																
11939																
Front																
Center																
Back																
11940																
Front																
Center																
Back																
11941																
Front																
Center																
Back																
11942																
Front									153.53	0.79	0.637	0.013				
Center	19517	500	54311	1997	134.6	3.4	374.4	13.8	151.56	0.55	0.617	0.011				
Back	20645	361	51827	1844	142.3	2.5	357.3	12.7	151.15	0.82	0.621	0.012				

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T494								IPST		IPST		T809			
Sample ID (#)	CD Young's Modulus (lbf/in^2)	95% C.I.	MD Young's Modulus (lbf/in^2)	95% C.I.	CD Young's Modulus (MN/m^2)	95% C.I.	MD Young's Modulus (MN/m^2)	95% C.I.	OD Basis Weight (g/m^2)	95% C.I.	OD Density (g/cm^3)	95% C.I.	Concora (lbf)	95% C.I.	Concora (N)	95% C.I.
11943																
Front	19489	810	51714	1126	134.4	5.6	356.5	7.8	148.64	0.68	0.619	0.015				
Center	18255	473	51820	2128	125.9	3.3	357.3	14.7	147.37	0.46	0.615	0.009				
Back	19577	661	50677	1635	135.0	4.6	349.4	11.3	148.62	0.76	0.636	0.016				
11944																
Front	20370	685	52108	2331	140.4	4.7	359.2	16.1	155.41	0.63	0.643	0.013				
Center	19917	629	53367	1579	137.3	4.3	367.9	10.9	153.87	0.53	0.613	0.012				
Back	20667	450	52348	1751	142.5	3.1	360.9	12.1	155.10	0.92	0.630	0.016				
11945																
Front	20960	398	53326	1116	144.5	2.7	367.7	7.7	154.49	0.73	0.633	0.017				
Center	19841	307	54710	1255	136.8	2.1	377.2	8.7	153.61	0.62	0.603	0.008				
Back	20506	394	52137	1020	141.4	2.7	359.5	7.0	153.53	0.70	0.613	0.013				
11946																
Front	20734	729	57862	9785	142.9	5.0	398.9	67.5	152.19	0.67	0.622	0.012				
Center	18855	469	54823	859	130.0	3.2	378.0	5.9	149.56	0.41	0.630	0.006				
Back	19306	587	53329	1350	133.1	4.0	367.7	9.3	153.14	0.71	0.651	0.005				
11947																
Front									150.29	0.62	0.635	0.011				
Center	18716	694	54137	808	129.0	4.8	373.2	5.6	150.36	0.51	0.626	0.006				
Back	19730	522	51601	950	136.0	3.6	355.8	6.5	149.17	0.69	0.645	0.009				
11948																
Front	19702	285	51015	1373	135.8	2.0	351.7	9.5	150.16	0.74	0.630	0.009				
Center	18389	261	51179	1038	126.8	1.8	352.8	7.2	149.54	0.49	0.632	0.006				
Back	19596	292	51203	1066	135.1	2.0	353.0	7.3	150.68	0.80	0.630	0.018				
11949																
Front	19328	460	49424	1288	133.3	3.2	340.7	8.9	152.46	0.78	0.637	0.013				
Center	17894	276	50068	778	123.4	1.9	345.2	5.4	150.00	0.46	0.628	0.010				
Back	18800	302	49999	1085	129.6	2.1	344.7	7.5	151.50	0.68	0.634	0.014				
11950																
Front	20977	391	52208	1776	144.6	2.7	359.9	12.2	149.15	0.54	0.663	0.012				
Center	20443	492	54043	2225	140.9	3.4	372.6	15.3	150.42	0.53	0.638	0.013				
Back	20558	330	48494	1126	141.7	2.3	334.3	7.8	149.30	0.64	0.650	0.013				

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T494								IPST		IPST		T809			
Sample ID (#)	CD Young's Modulus (lbf/in^2)	95% C.I.	MD Young's Modulus (lbf/in^2)	95% C.I.	CD Young's Modulus (MN/m^2)	95% C.I.	MD Young's Modulus (MN/m^2)	95% C.I.	OD Basis Weight (g/m^2)	95% C.I.	OD Density (g/cm^3)	95% C.I.	Concora (lbf)	95% C.I.	Concora (N)	95% C.I.
11951																
Front	19973	791	53967	1591	137.7	5.5	372.1	11.0	149.72	0.53	0.684	0.014				
Center	17928	659	55373	1592	123.6	4.5	381.8	11.0	149.42	0.46	0.663	0.016				
Back	20035	543	48910	1917	138.1	3.7	337.2	13.2	149.43	0.52	0.688	0.012				
11952																
Front	21083	288	53880	1766	145.4	2.0	371.5	12.2	147.29	0.46	0.694	0.014				
Center	20089	400	54969	1923	138.5	2.8	379.0	13.3	147.15	0.41	0.680	0.012				
Back	20244	307	51689	1794	139.6	2.1	356.4	12.4	146.82	0.39	0.677	0.015				
11953																
Front	20758	497	52874	1333	143.1	3.4	364.5	9.2	149.30	0.52	0.695	0.013				
Center	19454	323	52970	1078	134.1	2.2	365.2	7.4	149.55	0.53	0.679	0.014				
Back	20032	247	51845	1455	138.1	1.7	357.4	10.0	148.39	0.61	0.679	0.015				
11954																
Front	21820	371	51894	8283	150.4	2.6	357.8	57.1	151.64	0.49	0.692	0.016				
Center	19867	374	54368	1356	137.0	2.6	374.8	9.4	151.76	0.40	0.687	0.013				
Back	20317	367	50945	1558	140.1	2.5	351.2	10.7	151.44	0.53	0.679	0.014				
11955																
Front	20698	654	53975	1648	142.7	4.5	372.1	11.4	151.69	0.59	0.672	0.017				
Center	19461	493	54644	1307	134.2	3.4	376.7	9.0	152.38	0.54	0.640	0.017				
Back	20355	532	52396	1455	140.3	3.7	361.2	10.0	152.69	0.65	0.651	0.015				
11956																
Front	19903	930	53212	1341	137.2	6.4	366.9	9.2	151.80	0.57	0.690	0.017				
Center	19102	455	54504	1089	131.7	3.1	375.8	7.5	150.38	0.57	0.658	0.016				
Back	19910	267	51943	669	137.3	1.8	358.1	4.6	150.33	0.64	0.660	0.016				

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T494								IPST		IPST		T809			
Sample ID (#)	CD Young's Modulus (lbf/in^2)	95% C.I.	MD Young's Modulus (lbf/in^2)	95% C.I.	CD Young's Modulus (MN/m^2)	95% C.I.	MD Young's Modulus (MN/m^2)	95% C.I.	OD Basis Weight (g/m^2)	95% C.I.	OD Density (g/cm^3)	95% C.I.	Concora (lbf)	95% C.I.	Concora (N)	95% C.I.
Commercial Medium 107811																
Center	10887	226	36889	1075	75.1	1.6	254.3	7.4	115.64	0.61	0.616	0.010	49.05	2.71	218.17	12.06
Edge	10411	182	36201	642	71.8	1.3	249.6	4.4	116.97	0.47	0.616	0.009	50.23	1.10	223.40	4.89
107812																
Center	9949	285	35298	1124	68.6	2.0	243.4	7.8	115.07	5.56	0.636	0.033	49.25	1.86	219.06	8.29
Edge	10563	199	35596	589	72.8	1.4	245.4	4.1	115.02	0.46	0.629	0.008	48.45	1.13	215.51	5.03
107813																
Center	9704	359	33890	1864	66.9	2.5	233.6	12.9	112.91	0.69	0.626	0.014	47.85	3.01	212.84	13.40
Edge	9728	247	33210	726	67.1	1.7	229.0	5.0	114.67	0.43	0.637	0.009	50.18	1.32	223.18	5.87
107814																
Center	10328	238	37180	1692	71.2	1.6	256.3	11.7	116.77	0.86	0.618	0.012	51.15	1.93	227.52	8.59
Edge	10081	219	36322	1075	69.5	1.5	250.4	7.4	116.15	0.53	0.611	0.009	46.88	1.62	208.50	7.19
107816																
Center	10525	253	35841	2795	72.6	1.7	247.1	19.3	114.30	0.79	0.624	0.011	49.05	2.08	218.17	9.23
Edge	10186	499	36688	660	70.2	3.4	252.9	4.6	115.09	0.44	0.618	0.008	52.18	1.76	232.07	7.82
Commercial Liner 225111																
Center	18752	749	58356	1699	129.3	5.2	402.3	11.7	146.24	1.11	0.699	0.020				
Edge	18957	401	59941	2034	130.7	2.8	413.3	14.0	146.46	0.79	0.702	0.007				
225121																
Center	16664	1033	54236	2255	114.9	7.1	373.9	15.5	149.67	1.05	0.699	0.012				
Edge	18878	876	53573	1261	130.1	6.0	369.4	8.7	145.88	14.07	0.697	0.069				

Table E4. Combined Board Test Data.

Test Methods						T839							
Case Number (#)	Corrugator Group Order Code	Press Temp (°C)	Calendar Load (KN/m)	Inner Liner ID (#)	Outer Liner ID (#)	Center ECT (lbf/in)	95% C.I.	Center ECT (kN/m)	95% C.I.	Edge ECT (lbf/in)	95% C.I.	Edge ECT (kN/m)	95% C.I.
Case 1		**Commercial**	**Commercial**	**225121**	**225111**								
Group 1-10	1					29.50	1.11	5.17	0.19	28.99	0.73	5.08	0.13
Group 11-20	2					30.09	1.59	5.27	0.28	28.62	0.98	5.01	0.17
Group 21-30	3					29.71	1.24	5.20	0.22	29.89	1.06	5.23	0.19
Group 31-40	4					30.64	2.91	5.37	0.51	31.44	2.33	5.51	0.41
Average						**29.98**	**0.81**	**5.25**	**0.14**	**29.73**	**0.70**	**5.21**	**0.12**
Case 2A		**246**	**0**	**11930**	**11926**								
Group 1-10	5					26.48	2.19	4.64	0.38	30.50	1.11	5.34	0.19
Group 11-20	6					27.91	1.55	4.89	0.27	30.78	1.08	5.39	0.19
Group 21-30	7					26.46	0.73	4.63	0.13	29.23	1.42	5.12	0.25
Group 31-40	8					30.96	1.64	5.42	0.29	30.51	1.24	5.34	0.22
Average						**27.95**	**0.91**	**4.89**	**0.16**	**30.25**	**0.56**	**5.30**	**0.10**
Case 2B		**246**	**0**	**11931**	**11932**								
Group 1-10	9					28.82	1.13	5.05	0.20	28.92	1.34	5.06	0.23
Group 11-20	10					28.66	1.31	5.02	0.23	30.16	1.03	5.28	0.18
Group 21-30	11					26.44	2.53	4.63	0.44	29.39	1.18	5.15	0.21
Group 31-40	12					31.26	1.34	5.47	0.24	30.51	1.44	5.34	0.25
Average						**28.79**	**0.91**	**5.04**	**0.16**	**29.74**	**0.58**	**5.21**	**0.10**
Case 3		**wp**	**35**	**11949**	**11948**								
Group 1-10	13					26.51	1.12	4.64	0.20	25.64	1.13	4.49	0.20
Group 11-20	14					28.20	0.41	4.94	0.07	28.08	0.66	4.92	0.12
Group 21-30	15					25.42	1.61	4.45	0.28	26.72	1.04	4.68	0.18
Group 31-40	16					27.97	1.75	4.90	0.31	23.61	0.99	4.13	0.17
Average						**27.02**	**0.68**	**4.73**	**0.12**	**26.01**	**0.67**	**4.55**	**0.12**
Case 4		**260**	**0**	**11935**	**11936**								
Group 1-10	17					28.19	1.60	4.94	0.28	31.17	0.99	5.46	0.17
Group 11-20	18					30.47	0.86	5.33	0.15	31.88	0.85	5.58	0.15
Group 21-30	19					28.64	0.92	5.02	0.16	30.03	1.48	5.26	0.26
Group 31-40	20					23.94	1.63	4.19	0.29	27.43	2.30	4.80	0.40
Average						**27.81**	**0.96**	**4.87**	**0.17**	**30.13**	**0.85**	**5.28**	**0.15**

Table E4 cont. Combined Board Test Data.

Test Methods						T839							
Case Number (#)	Corrugator Group Order Code	Press Temp (°C)	Calendar Load (KN/m)	Inner Liner ID (#)	Outer Liner ID (#)	Center ECT (lbf/in)	95% C.I.	Center ECT (kN/m)	95% C.I.	Edge ECT (lbf/in)	95% C.I.	Edge ECT (kN/m)	95% C.I.
Case 5		**wp**	**0**	**11944**	**11945**								
Group 1-10	21					26.04	1.21	4.56	0.21	27.85	0.72	4.88	0.13
Group 11-20	22					28.62	1.15	5.01	0.20	27.70	1.18	4.85	0.21
Group 21-30	23					25.71	1.42	4.50	0.25	27.33	1.27	4.79	0.22
Group 31-40	24					23.81	2.75	4.17	0.48	24.69	1.77	4.32	0.31
Average						**26.04**	**0.94**	**4.56**	**0.16**	**26.89**	**0.69**	**4.71**	**0.12**
Case 6		**246**	**35**	**11927**	**11928**								
Group 1-10	25					26.33	1.17	4.61	0.20	26.36	0.66	4.62	0.12
Group 11-20	26					24.31	1.87	4.26	0.33	26.22	1.88	4.59	0.33
Group 21-30	27					26.91	0.97	4.71	0.17	27.47	1.07	4.81	0.19
Group 31-40	28					28.03	0.91	4.91	0.16	28.35	1.63	4.96	0.28
Average						**26.39**	**0.71**	**4.62**	**0.12**	**27.10**	**0.66**	**4.75**	**0.12**

Table E4 cont. Combined Board Test Data.

Test Methods	IPST				T411		IPST		T411		IPST		T821			
Case Number (#)	Center Glue Weight (gsm)	95% C.I.	Edge Glue Weight (gsm)	95% C.I.	Center Combined Caliper (mm)	95% C.I.	Center Flute Caliper (mm)	95% C.I.	Edge Combined Caliper (mm)	95% C.I.	Edge Flute Caliper (mm)	95% C.I.	Single Face Center Pin Adhesion (lbf/ft)	95% C.I.	Single Face Edge Pin Adhesion (lbf/ft)	95% C.I.
Case 1																
Group 1-10	15.33	7.05	21.75	3.31	3.93	0.03	3.51	0.03	4.04	0.01	3.62	0.01	41.91	3.42	38.95	3.26
Group 11-20	18.31	4.47	22.91	3.29	3.96	0.03	3.53	0.03	4.04	0.02	3.62	0.02	41.42	2.89	40.90	3.21
Group 21-30	18.93	4.12	15.32	6.32	3.98	0.04	3.56	0.04	3.98	0.02	3.56	0.02	39.93	2.58	44.75	2.08
Group 31-40	19.71	5.14	22.56	4.26	4.01	0.03	3.58	0.03	4.03	0.02	3.61	0.02	39.03	5.15	35.91	3.47
Average	**18.07**	**2.35**	**20.64**	**2.17**	**3.97**	**0.02**	**3.55**	**0.02**	**4.02**	**0.01**	**3.60**	**0.01**	**40.57**	**1.61**	**40.12**	**1.67**
Case 2A																
Group 1-10	20.22	4.91	23.05	4.95	3.74	0.09	3.30	0.09	3.91	0.02	3.47	0.02	41.61	3.75	42.94	1.45
Group 11-20	20.18	2.69	21.58	4.83	3.80	0.03	3.36	0.03	3.88	0.02	3.44	0.02	30.92	4.07	31.20	3.61
Group 21-30	18.63	3.78	20.46	5.30	3.74	0.04	3.30	0.04	3.77	0.03	3.33	0.03	30.96	2.66	32.66	3.36
Group 31-40	17.89	4.04	17.55	5.07	3.83	0.04	3.39	0.04	3.81	0.04	3.37	0.04	42.34	1.71	40.32	1.61
Average	**19.23**	**1.72**	**20.66**	**2.26**	**3.78**	**0.03**	**3.34**	**0.03**	**3.84**	**0.02**	**3.41**	**0.02**	**36.46**	**2.25**	**36.78**	**1.98**
Case 2B																
Group 1-10	27.07	3.43	26.70	4.32	3.62	0.06	3.19	0.06	3.62	0.05	3.19	0.05	39.19	1.58	37.46	2.58
Group 11-20	24.01	4.02	26.43	3.75	3.71	0.02	3.27	0.03	3.69	0.03	3.26	0.03	39.00	4.15	36.43	2.22
Group 21-30	24.67	4.68	29.53	4.72	3.57	0.07	3.14	0.07	3.65	0.04	3.22	0.04	36.43	1.74	35.41	1.43
Group 31-40	25.48	2.50	28.29	3.29	3.85	0.04	3.41	0.04	3.70	0.05	3.27	0.05	41.29	2.19	40.32	1.49
Average	**25.31**	**1.65**	**27.74**	**1.79**	**3.69**	**0.03**	**3.25**	**0.03**	**3.67**	**0.02**	**3.24**	**0.02**	**38.97**	**1.26**	**37.40**	**1.04**
Case 3																
Group 1-10	19.92	3.61	20.49	2.44	3.67	0.04	3.19	0.04	3.75	0.04	3.27	0.04	50.32	2.84	50.89	1.60
Group 11-20	20.46	3.31	23.39	3.50	3.76	0.02	3.28	0.02	3.81	0.02	3.33	0.02	43.37	1.48	45.46	2.02
Group 21-30	19.80	2.68	21.92	3.09	3.64	0.05	3.16	0.05	3.71	0.04	3.23	0.04	37.65	1.90	37.83	1.60
Group 31-40	26.66	3.00	21.92	4.01	3.82	0.06	3.34	0.06	3.63	0.08	3.15	0.08	48.58	2.48	47.73	1.57
Average	**21.71**	**1.65**	**21.93**	**1.46**	**3.72**	**0.03**	**3.24**	**0.02**	**3.73**	**0.03**	**3.25**	**0.02**	**44.98**	**1.87**	**45.48**	**1.72**
Case 4																
Group 1-10	29.12	3.70	31.78	3.96	3.56	0.11	3.13	0.11	3.77	0.02	3.34	0.02	33.75	1.74	30.90	1.99
Group 11-20	29.27	3.05	31.82	3.85	3.80	0.02	3.37	0.02	3.87	0.02	3.44	0.02	37.84	1.11	33.94	1.21
Group 21-30	28.73	2.72	28.68	5.02	3.71	0.06	3.27	0.06	3.84	0.03	3.41	0.03	42.18	5.97	41.22	4.40
Group 31-40	23.34	3.22	27.75	4.13	3.49	0.09	3.06	0.09	3.62	0.07	3.19	0.07	44.23	2.21	45.85	1.75
Average	**27.62**	**1.59**	**30.01**	**1.92**	**3.64**	**0.04**	**3.21**	**0.04**	**3.78**	**0.03**	**3.34**	**0.02**	**39.50**	**1.94**	**37.98**	**2.22**

Table E4 cont. Combined Board Test Data.

Test Methods	IPST				T411		IPST		T411		IPST		T821			
Case Number (#)	Center Glue Weight (gsm)	95% C.I.	Edge Glue Weight (gsm)	95% C.I.	Center Combined Caliper (mm)	95% C.I.	Center Flute Caliper (mm)	95% C.I.	Edge Combined Caliper (mm)	95% C.I.	Edge Flute Caliper (mm)	95% C.I.	Single Face Center Pin Adhesion (lbf/ft)	95% C.I.	Single Face Edge Pin Adhesion (lbf/ft)	95% C.I.
Case 5																
Group 1-10	12.01	5.51	15.68	4.76	3.68	0.16	3.17	0.16	3.91	0.02	3.42	0.02	51.50	1.37	50.66	2.53
Group 11-20	21.93	2.97	20.91	4.20	3.85	0.02	3.34	0.02	3.85	0.02	3.35	0.02	49.72	1.53	50.91	1.33
Group 21-30	16.04	3.19	13.16	5.25	3.73	0.08	3.22	0.08	3.75	0.04	3.25	0.04	47.91	2.10	49.05	2.86
Group 31-40	16.39	4.63	19.09	4.36	3.70	0.10	3.19	0.10	3.66	0.07	3.16	0.07	50.77	1.85	52.56	2.83
Average	**16.60**	**2.14**	**17.21**	**2.23**	**3.74**	**0.05**	**3.23**	**0.05**	**3.79**	**0.03**	**3.29**	**0.02**	**49.97**	**0.86**	**50.79**	**1.13**
Case 6																
Group 1-10	21.57	4.60	20.50	4.76	3.65	0.04	3.24	0.04	3.64	0.04	3.23	0.04	47.08	4.26	45.02	2.61
Group 11-20	22.27	4.20	25.19	3.89	3.62	0.05	3.20	0.05	3.59	0.08	3.17	0.08	42.37	2.26	43.19	2.98
Group 21-30	21.65	3.01	25.96	4.84	3.62	0.03	3.20	0.03	3.59	0.08	3.18	0.08	38.86	2.19	35.00	2.89
Group 31-40	25.99	2.84	24.02	2.39	3.58	0.04	3.17	0.04	3.55	0.05	3.13	0.05	38.44	2.42	38.32	1.40
Average	**22.87**	**1.71**	**23.92**	**1.88**	**3.62**	**0.02**	**3.20**	**0.02**	**3.59**	**0.03**	**3.18**	**0.03**	**41.69**	**1.68**	**40.38**	**1.69**

Table E4 cont. Combined Board Test Data.

Test Methods	T821											
Case Number (#)	Double Face Center Pin Adhesion (lbf/ft)	95% C.I.	Double Face Edge Pin Adhesion (lbf/ft)	95% C.I.	Single Face Center Pin Adhesion (N/m)	95% C.I.	Single Face Edge Pin Adhesion (N/m)	95% C.I.	Double Face Center Pin Adhesion (N/m)	95% C.I.	Double Face Edge Pin Adhesion (N/m)	95% C.I.
Case 1												
Group 1-10	44.49	3.21	39.58	3.26	611.56	49.91	568.36	47.60	649.21	46.89	577.63	47.57
Group 11-20	41.12	3.33	38.46	3.73	604.41	42.23	596.89	46.86	600.10	48.64	561.28	54.42
Group 21-30	39.47	5.03	40.91	4.00	582.66	37.60	653.00	30.36	575.95	73.48	597.04	58.38
Group 31-40	46.76	4.41	41.44	6.72	569.53	75.12	523.99	50.63	682.34	64.29	604.77	98.02
Average	**42.96**	**1.98**	**40.10**	**2.02**	**592.04**	**23.50**	**585.56**	**24.42**	**626.90**	**28.82**	**585.18**	**29.52**
Case 2A												
Group 1-10	50.75	2.86	48.88	2.14	607.25	54.68	626.59	21.18	740.64	41.68	713.35	31.25
Group 11-20	44.21	2.72	43.96	4.51	451.24	59.35	455.33	52.74	645.20	39.73	641.55	65.83
Group 21-30	42.56	1.89	39.01	3.78	451.83	38.89	476.56	48.99	621.04	27.58	569.31	55.23
Group 31-40	56.14	1.68	54.13	1.46	617.83	25.02	588.43	23.54	819.30	24.54	789.97	21.31
Average	**48.41**	**2.02**	**46.50**	**2.29**	**532.04**	**32.87**	**536.73**	**28.91**	**706.54**	**29.50**	**678.54**	**33.36**
Case 2B												
Group 1-10	50.69	3.41	48.51	2.22	571.86	23.08	546.69	37.70	739.69	49.71	707.88	32.41
Group 11-20	45.88	3.51	47.10	1.99	569.09	60.56	531.66	32.45	669.49	51.17	687.37	29.03
Group 21-30	48.59	3.01	46.40	1.64	531.58	25.43	516.70	20.83	709.04	43.99	677.08	23.93
Group 31-40	60.94	2.10	57.59	3.92	602.58	32.00	588.43	21.77	889.35	30.70	840.46	57.23
Average	**51.52**	**2.27**	**49.90**	**1.84**	**568.78**	**18.37**	**545.87**	**15.20**	**751.90**	**33.06**	**728.20**	**26.80**
Case 3												
Group 1-10	52.09	2.09	49.64	1.39	734.29	41.38	742.68	23.36	760.12	30.52	724.44	20.25
Group 11-20	49.07	8.61	49.79	1.79	632.86	21.53	663.44	29.50	716.12	#####	726.56	26.16
Group 21-30	46.58	2.99	43.82	2.68	549.39	27.70	552.01	23.37	679.78	43.69	639.50	39.11
Group 31-40	54.94	1.93	53.57	1.81	708.97	36.13	696.49	22.90	801.79	28.11	781.79	26.34
Average	**50.67**	**2.29**	**49.20**	**1.41**	**656.38**	**27.25**	**663.66**	**25.17**	**739.45**	**33.41**	**718.07**	**20.60**
Case 4												
Group 1-10	42.66	1.97	37.12	2.20	492.47	25.33	450.95	29.04	622.50	28.72	541.73	32.10
Group 11-20	45.02	1.54	40.44	2.72	552.23	16.15	495.32	17.69	656.94	22.48	590.18	39.67
Group 21-30	44.28	3.39	42.10	3.92	615.50	87.11	601.49	64.20	646.14	49.48	614.40	57.20
Group 31-40	51.13	3.81	49.45	2.85	645.49	32.23	669.13	25.55	746.11	55.60	721.67	41.60
Average	**45.77**	**1.60**	**42.28**	**1.95**	**576.42**	**28.37**	**554.22**	**32.39**	**667.93**	**23.39**	**616.99**	**28.39**

Table E4 cont. Combined Board Test Data.

Test Methods	T821											
Case Number (#)	Double Face Center Pin Adhesion (lbf/ft)	95% C.I.	Double Face Edge Pin Adhesion (lbf/ft)	95% C.I.	Single Face Center Pin Adhesion (N/m)	95% C.I.	Single Face Edge Pin Adhesion (N/m)	95% C.I.	Double Face Center Pin Adhesion (N/m)	95% C.I.	Double Face Edge Pin Adhesion (N/m)	95% C.I.
Case 5												
Group 1-10	46.40	2.21	40.82	2.46	751.51	20.03	739.33	36.96	677.08	32.18	595.72	35.94
Group 11-20	53.08	2.36	46.50	1.17	725.61	22.35	742.90	19.45	774.57	34.40	678.62	17.14
Group 21-30	48.08	2.59	39.94	5.47	699.19	30.58	715.83	41.71	701.67	37.85	582.88	79.86
Group 31-40	48.03	1.89	48.42	1.69	740.86	26.94	767.05	41.28	700.94	27.61	706.56	24.65
Average	**48.90**	**1.27**	**43.92**	**1.80**	**729.29**	**12.60**	**741.28**	**16.55**	**713.57**	**18.55**	**640.95**	**26.22**
Case 6												
Group 1-10	47.55	2.12	47.42	2.64	687.01	62.13	657.02	38.08	693.87	30.99	691.97	38.55
Group 11-20	54.11	2.50	52.45	3.10	618.34	33.04	630.31	43.49	789.60	36.47	765.38	45.27
Group 21-30	47.86	4.56	40.89	3.93	567.12	31.90	510.71	42.14	698.39	66.52	596.74	57.32
Group 31-40	47.88	3.18	44.90	2.55	560.99	35.28	559.24	20.47	698.76	46.43	655.27	37.28
Average	**49.35**	**1.65**	**46.41**	**1.90**	**608.36**	**24.52**	**589.32**	**24.61**	**720.15**	**24.05**	**677.34**	**27.76**

Table E4 cont. Combined Board Test Data.

Test Methods	T825								T836							
Case Number (#)	Center Flat Crush (psi)	95% C.I.	Edge Flat Crush (psi)	95% C.I.	Center Flat Crush (kPa)	95% C.I.	Edge Flat Crush (kPa)	95% C.I.	MD Flexural Stiffness (lb-in)	95% C.I.	CD Flexural Stiffness (lb-in)	95% C.I.	MD Flexural Stiffness (N-m)	95% C.I.	CD Flexural Stiffness (N-m)	95% C.I.
Case 1																
Group 1-10	21.20	1.45	27.27	2.63	146.15	10.01	188.01	18.12	98.82	4.36	43.21	0.98	11.16	0.49	4.88	0.11
Group 11-20	28.46	1.38	22.97	5.36	196.21	9.50	158.39	36.98	105.26	2.58	43.53	0.63	11.89	0.29	4.92	0.07
Group 21-30	29.63	3.06	29.48	1.21	204.30	21.08	203.28	8.32	87.85	17.83	43.69	0.59	9.93	2.01	4.94	0.07
Group 31-40	28.73	1.75	29.87	0.70	198.09	12.07	205.92	4.85	56.03	28.98	45.64	0.66	6.33	3.27	5.16	0.07
Average	**27.00**	**1.40**	**27.40**	**1.59**	**186.19**	**9.64**	**188.90**	**10.95**	**86.99**	**9.60**	**44.02**	**0.44**	**9.83**	**1.08**	**4.97**	**0.05**
Case 2A																
Group 1-10	21.15	1.05	22.31	0.50	145.80	7.23	153.83	3.47	71.92	17.82	38.43	0.35	8.13	2.01	4.34	0.04
Group 11-20	24.44	1.14	24.48	1.40	168.51	7.85	168.79	9.66	88.29	2.55	38.09	0.52	9.97	0.29	4.30	0.06
Group 21-30	24.53	0.62	24.83	1.47	169.16	4.28	171.18	10.12	82.94	4.85	37.09	0.80	9.37	0.55	4.19	0.09
Group 31-40	27.18	0.68	25.60	1.23	187.42	4.69	176.53	8.49	65.01	17.09	39.44	0.24	7.35	1.93	4.46	0.03
Average	**24.33**	**0.79**	**24.31**	**0.65**	**167.72**	**5.47**	**167.58**	**4.51**	**77.04**	**6.18**	**38.27**	**0.35**	**8.70**	**0.70**	**4.32**	**0.04**
Case 2B																
Group 1-10	22.43	1.31	22.08	0.75	154.62	9.01	152.26	5.18	79.22	2.25	33.33	0.45	8.95	0.25	3.77	0.05
Group 11-20	21.84	1.46	23.17	1.25	150.57	10.07	159.78	8.63	75.83	9.37	34.06	0.63	8.57	1.06	3.85	0.07
Group 21-30	21.89	1.19	23.90	0.85	150.90	8.21	164.79	5.84	79.39	1.34	33.57	0.64	8.97	0.15	3.79	0.07
Group 31-40	24.15	0.54	25.66	1.00	166.51	3.73	176.95	6.91	88.29	24.96	37.75	0.79	9.98	2.82	4.27	0.09
Average	**22.57**	**0.59**	**23.70**	**0.60**	**155.65**	**4.07**	**163.44**	**4.11**	**80.68**	**5.94**	**34.68**	**0.64**	**9.12**	**0.67**	**3.92**	**0.07**
Case 3																
Group 1-10	18.89	0.93	19.17	1.21	130.25	6.44	132.17	8.33	76.25	1.95	30.73	0.53	8.61	0.22	3.47	0.06
Group 11-20	22.02	1.09	18.93	0.73	151.83	7.49	130.52	5.02	76.64	1.05	30.92	0.53	8.66	0.12	3.49	0.06
Group 21-30	22.02	1.66	22.09	1.80	151.81	11.43	152.29	12.40	75.09	1.61	30.10	0.62	8.48	0.18	3.40	0.07
Group 31-40	28.68	0.71	29.36	1.47	197.75	4.93	202.44	10.12	87.10	3.82	34.47	1.79	9.84	0.43	3.89	0.20
Average	**22.90**	**1.26**	**22.39**	**1.48**	**157.91**	**8.68**	**154.35**	**10.24**	**78.77**	**1.87**	**31.56**	**0.71**	**8.90**	**0.21**	**3.57**	**0.08**
Case 4																
Group 1-10	24.92	0.38	25.70	2.17	171.84	2.61	177.19	14.97	85.28	3.52	36.39	0.93	9.63	0.40	4.11	0.11
Group 11-20	28.26	1.66	25.98	1.37	194.84	11.43	179.13	9.43	89.90	1.67	37.95	0.90	10.16	0.19	4.29	0.10
Group 21-30	23.29	1.22	24.11	1.76	160.57	8.41	166.25	12.12	82.44	14.78	38.24	1.09	9.31	1.67	4.32	0.12
Group 31-40	27.48	1.27	27.46	2.08	189.50	8.76	189.30	14.34	90.04	2.02	39.76	0.88	10.17	0.23	4.49	0.10
Average	**25.99**	**0.83**	**25.81**	**0.89**	**179.19**	**5.73**	**177.97**	**6.14**	**86.91**	**3.47**	**38.08**	**0.56**	**9.82**	**0.39**	**4.30**	**0.06**

Table E4 cont. Combined Board Test Data.

Test Methods	T825								T836							
Case Number (#)	Center Flat Crush (psi)	95% C.I.	Edge Flat Crush (psi)	95% C.I.	Center Flat Crush (kPa)	95% C.I.	Edge Flat Crush (kPa)	95% C.I.	MD Flexural Stiffness (lb-in)	95% C.I.	CD Flexural Stiffness (lb-in)	95% C.I.	MD Flexural Stiffness (N-m)	95% C.I.	CD Flexural Stiffness (N-m)	95% C.I.
Case 5																
Group 1-10	24.19	1.93	23.39	0.89	166.82	13.34	161.26	6.13	74.34	24.37	33.19	2.28	8.40	2.75	3.75	0.26
Group 11-20	23.19	0.96	25.95	0.67	159.92	6.64	178.91	4.63	76.22	14.05	33.66	0.77	8.61	1.59	3.80	0.09
Group 21-30	23.28	0.87	25.39	1.16	160.52	5.97	175.06	8.01	72.56	7.87	32.09	1.04	8.20	0.89	3.62	0.12
Group 31-40	26.67	1.28	28.40	0.54	183.91	8.80	195.84	3.73	89.02	3.09	35.54	1.31	10.06	0.35	4.02	0.15
Average	**24.34**	**0.73**	**25.78**	**0.68**	**167.79**	**5.03**	**177.77**	**4.72**	**78.03**	**6.65**	**33.62**	**0.75**	**8.82**	**0.75**	**3.80**	**0.08**
Case 6																
Group 1-10	18.87	0.94	20.22	0.52	130.07	6.49	139.42	3.56	74.73	11.33	34.57	1.13	8.44	1.28	3.91	0.13
Group 11-20	27.23	1.67	26.62	3.14	187.78	11.48	183.52	21.65	102.49	25.25	38.07	0.75	11.58	2.85	4.30	0.08
Group 21-30	20.77	1.22	21.50	1.42	143.24	8.40	148.21	9.79	68.19	9.26	34.81	1.01	7.70	1.05	3.93	0.11
Group 31-40	20.35	0.77	22.34	0.90	140.31	5.32	154.05	6.22	66.10	13.72	35.59	1.20	7.47	1.55	4.02	0.14
Average	**21.81**	**1.16**	**22.67**	**1.10**	**150.35**	**8.00**	**156.30**	**7.56**	**77.88**	**8.38**	**35.76**	**0.63**	**8.80**	**0.95**	**4.04**	**0.07**

Table E4 cont. Combined Board Test Data.

Test Methods	T411		IPST	T411		IPST
Case Number (#)	MD Flex Combined Caliper (mm)	95% C.I.	MD Flex Flute Caliper (mm)	CD Flex Combined Caliper (mm)	95% C.I.	CD Flex Flute Caliper (mm)
Case 1						
Group 1-10	4.01	0.02	4.00	4.01	0.01	4.01
Group 11-20	4.02	0.01	4.01	4.01	0.01	4.00
Group 21-30	4.05	0.01	4.04	4.04	0.01	4.03
Group 31-40	4.07	0.02	4.07	4.09	0.01	4.09
Average	**4.04**	**0.01**		**4.04**	**0.01**	
Case 2A						
Group 1-10	3.82	0.03	3.81	3.82	0.02	3.82
Group 11-20	3.84	0.01	3.83	3.81	0.02	3.81
Group 21-30	3.75	0.02	3.75	3.73	0.02	3.72
Group 31-40	3.86	0.01	3.85	3.87	0.01	3.87
Average	**3.82**	**0.01**		**3.81**	**0.02**	
Case 2B						
Group 1-10	3.72	0.02	3.70	3.66	0.02	3.65
Group 11-20	3.71	0.02	3.70	3.64	0.03	3.63
Group 21-30	3.67	0.03	3.66	3.62	0.05	3.61
Group 31-40	3.82	0.02	3.81	3.83	0.02	3.82
Average	**3.73**	**0.02**		**3.69**	**0.02**	
Case 3						
Group 1-10	3.74	0.02	3.73	3.70	0.04	3.69
Group 11-20	3.77	0.01	3.76	3.71	0.02	3.71
Group 21-30	3.71	0.03	3.71	3.67	0.02	3.66
Group 31-40	3.87	0.06	3.86	3.83	0.08	3.83
Average	**3.77**	**0.02**		**3.73**	**0.03**	
Case 4						
Group 1-10	3.75	0.04	3.74	3.73	0.04	3.72
Group 11-20	3.83	0.01	3.83	3.80	0.03	3.79
Group 21-30	3.83	0.03	3.83	3.80	0.03	3.79
Group 31-40	3.86	0.05	3.85	3.85	0.04	3.84
Average	**3.82**	**0.02**		**3.79**	**0.02**	

Table E4 cont. Combined Board Test Data.

Test Methods	T411		IPST	T411		IPST
Case Number (#)	MD Flex Combined Caliper (mm)	95% C.I.	MD Flex Flute Caliper (mm)	CD Flex Combined Caliper (mm)	95% C.I.	CD Flex Flute Caliper (mm)
Case 5						
Group 1-10	3.69	0.19	3.68	3.78	0.09	3.77
Group 11-20	3.88	0.01	3.87	3.84	0.02	3.83
Group 21-30	3.75	0.03	3.74	3.73	0.03	3.72
Group 31-40	3.90	0.04	3.90	3.88	0.04	3.87
Average	**3.81**	**0.05**		**3.81**	**0.03**	
Case 6						
Group 1-10	3.69	0.04	3.69	3.68	0.03	3.67
Group 11-20	3.78	0.06	3.77	3.81	0.02	3.81
Group 21-30	3.66	0.04	3.66	3.66	0.04	3.66
Group 31-40	3.66	0.03	3.66	3.67	0.02	3.66
Average	**3.70**	**0.02**		**3.70**	**0.02**	

Table E5. Box Test Data.

Test Methods						T813			
Case Number (#)	Corrugator Group Order Code	Press Temp (°C)	Calendar Load (KN/m)	Inner Liner ID (#)	Outer Liner ID (#)	Manufactures Glue Joint (lbf/in)	95% C.I.	Manufactures Glue Joint (kN/m)	95% C.I.
Case 1		**Commercial**	**Commercial**	**225121**	**225111**				
Group 1-10	1					91.16	3.37	15.96	0.59
Group 11-20	2					92.16	5.34	16.14	0.94
Group 21-30	3					90.99	3.91	15.93	0.68
Average						**91.44**	**2.17**	**16.01**	**0.38**
Case 2A		**246**	**0**	**11930**	**11926**				
Group 1-10	5					53.41	7.90	9.35	1.38
Group 11-20	6					47.98	5.83	8.40	1.02
Group 21-30	7					50.68	6.56	8.87	1.15
Average						**50.69**	**3.54**	**8.88**	**0.62**
Case 2B		**246**	**0**	**11931**	**11932**				
Group 1-10	9					68.71	5.86	12.03	1.03
Group 11-20	10					69.42	3.78	12.16	0.66
Group 21-30	11					71.09	4.89	12.45	0.86
Average						**69.74**	**2.51**	**12.21**	**0.44**
Case 3		**wp**	**35**	**11949**	**11948**				
Group 1-10	13					58.82	7.59	10.30	1.33
Group 11-20	14					52.39	4.08	9.17	0.71
Group 21-30	15					58.51	8.18	10.25	1.43
Average						**56.57**	**3.63**	**9.91**	**0.64**
Case 4		**260**	**0**	**11935**	**11936**				
Group 1-10	17					59.85	5.47	10.48	0.96
Group 11-20	18					64.61	5.43	11.31	0.95
Group 21-30	19					65.08	5.52	11.40	0.97
Average						**63.18**	**2.90**	**11.06**	**0.51**
Case 5		**wp**	**0**	**11944**	**11945**				
Group 1-10	21					61.26	5.80	10.73	1.02
Group 11-20	22					58.44	2.36	10.23	0.41
Group 21-30	23					56.97	5.98	9.98	1.05
Average						**58.89**	**2.61**	**10.31**	**0.46**

Table E5 cont. Box Test Data.

Test Methods	T804							
Case Number (#)	Top-Bottom Box Peak Load (lbf)	95% C.I.	Top-Bottom Deflection @ Peak Load (in)	95% C.I.	Top-Bottom Box Peak Load (kN)	95% C.I.	Top-Bottom Box @ Peak Load (mm)	95% C.I.
Case 1								
Group 1-10	462.40	33.25	0.39	0.02	2.06	0.15	10.01	0.53
Group 11-20	431.90	31.11	0.39	0.02	1.92	0.14	10.01	0.49
Group 21-30	447.80	14.64	0.41	0.02	1.99	0.07	10.44	0.50
Average	**447.37**	**14.69**	**0.40**	**0.01**	**1.99**	**0.07**	**10.15**	**0.27**
Case 2A								
Group 1-10	518.70	39.35	0.40	0.02	2.31	0.18	10.24	0.59
Group 11-20	411.50	79.24	0.45	0.11	1.83	0.35	11.48	2.74
Group 21-30	422.00	20.90	0.40	0.01	1.88	0.09	10.11	0.19
Average	**450.73**	**32.17**	**0.42**	**0.03**	**2.00**	**0.14**	**10.61**	**0.85**
Case 2B								
Group 1-10	497.30	16.52	0.39	0.01	2.21	0.07	10.01	0.32
Group 11-20	432.10	27.09	0.39	0.01	1.92	0.12	9.83	0.34
Group 21-30	449.30	49.42	0.40	0.02	2.00	0.22	10.11	0.55
Average	**459.57**	**20.04**	**0.39**	**0.01**	**2.04**	**0.09**	**9.98**	**0.22**
Case 3								
Group 1-10	456.10	20.33	0.38	0.02	2.03	0.09	9.65	0.49
Group 11-20	408.90	33.30	0.35	0.01	1.82	0.15	8.86	0.29
Group 21-30	380.00	25.55	0.37	0.01	1.69	0.11	9.35	0.33
Average	**415.00**	**18.05**	**0.37**	**0.01**	**1.85**	**0.08**	**9.29**	**0.23**
Case 4								
Group 1-10	500.50	33.26	0.42	0.05	2.23	0.15	10.54	1.34
Group 11-20	475.40	30.88	0.39	0.01	2.11	0.14	9.98	0.30
Group 21-30	469.50	57.71	0.41	0.02	2.09	0.26	10.44	0.45
Average	**481.80**	**21.95**	**0.41**	**0.02**	**2.14**	**0.10**	**10.32**	**0.43**
Case 5								
Group 1-10	417.70	35.46	0.40	0.03	1.86	0.16	10.03	0.84
Group 11-20	446.90	19.37	0.41	0.03	1.99	0.09	10.52	0.69
Group 21-30	446.30	45.16	0.42	0.04	1.99	0.20	10.64	1.12
Average	**436.97**	**18.37**	**0.41**	**0.02**	**1.94**	**0.08**	**10.40**	**0.46**

Table E5 cont. Box Test Data.

Test Methods	T804							
Case Number (#)	Side-Side Box Peak Load (lbf)	95% C.I.	Side-Side Deflection @ Peak Load (in)	95% C.I.	Side-Side Box Peak Load (kN)	95% C.I.	Side-Side Box @ Peak Load (mm)	95% C.I.
Case 1								
Group 1-10	391.50	25.43	0.54	0.09	1.74	0.11	13.77	2.16
Group 11-20	340.40	28.43	0.65	0.08	1.51	0.13	16.43	1.92
Group 21-30	360.70	33.94	0.59	0.07	1.60	0.15	14.99	1.77
Average	**364.20**	**16.85**	**0.59**	**0.04**	**1.62**	**0.07**	**15.06**	**1.07**
Case 2A								
Group 1-10	347.20	45.95	0.54	0.17	1.54	0.20	13.72	4.38
Group 11-20	391.80	10.04	0.54	0.04	1.74	0.04	13.69	1.07
Group 21-30	370.20	26.46	0.56	0.05	1.65	0.12	14.25	1.27
Average	**369.73**	**17.15**	**0.55**	**0.05**	**1.64**	**0.08**	**13.89**	**1.37**
Case 2B								
Group 1-10	334.80	13.42	0.48	0.04	1.49	0.06	12.22	1.12
Group 11-20	373.50	30.50	0.45	0.08	1.66	0.14	11.30	2.01
Group 21-30	327.20	28.20	0.44	0.11	1.46	0.13	11.13	2.88
Average	**345.17**	**14.85**	**0.45**	**0.04**	**1.54**	**0.07**	**11.55**	**1.09**
Case 3								
Group 1-10	354.70	27.95	0.47	0.05	1.58	0.12	12.04	1.26
Group 11-20	295.20	22.66	0.31	0.13	1.31	0.10	7.87	3.25
Group 21-30	322.00	24.84	0.39	0.11	1.43	0.11	9.96	2.91
Average	**323.97**	**15.72**	**0.39**	**0.06**	**1.44**	**0.07**	**9.96**	**1.47**
Case 4								
Group 1-10	432.80	17.08	0.51	0.03	1.93	0.08	13.03	0.80
Group 11-20	400.40	29.35	0.48	0.07	1.78	0.13	12.09	1.87
Group 21-30	351.10	26.47	0.51	0.05	1.56	0.12	13.03	1.35
Average	**394.77**	**17.88**	**0.50**	**0.03**	**1.76**	**0.08**	**12.72**	**0.73**
Case 5								
Group 1-10	431.10	27.22	0.46	0.04	1.92	0.12	11.66	0.89
Group 11-20	384.10	37.22	0.42	0.08	1.71	0.17	10.69	1.92
Group 21-30	312.00	15.16	0.36	0.08	1.39	0.07	9.02	2.07
Average	**375.73**	**23.35**	**0.41**	**0.04**	**1.67**	**0.10**	**10.46**	**0.96**

Table E5 cont. Box Test Data.

Test Methods	T804							
Case Number (#)	End-End Box Peak Load (lbf)	95% C.I.	End-End Deflection @ Peak Load (in)	95% C.I.	End-End Box Peak Load (kN)	95% C.I.	End-End Box @ Peak Load (mm)	95% C.I.
Case 1								
Group 1-10	284.80	24.00	0.24	0.04	1.27	0.11	6.17	0.94
Group 11-20	291.50	20.29	0.27	0.04	1.30	0.09	6.83	0.92
Group 21-30	278.10	28.00	0.22	0.02	1.24	0.12	5.69	0.58
Average	**284.80**	**12.41**	**0.25**	**0.02**	**1.27**	**0.06**	**6.23**	**0.45**
Case 2A								
Group 1-10	297.40	36.22	0.24	0.03	1.32	0.16	6.02	0.64
Group 11-20	317.40	18.95	0.24	0.03	1.41	0.08	6.07	0.81
Group 21-30	303.50	18.85	0.25	0.03	1.35	0.08	6.22	0.69
Average	**306.10**	**13.47**	**0.24**	**0.01**	**1.36**	**0.06**	**6.10**	**0.36**
Case 2B								
Group 1-10	262.00	26.87	0.31	0.18	1.17	0.12	7.87	4.57
Group 11-20	267.70	25.73	0.25	0.05	1.19	0.11	6.30	1.18
Group 21-30	259.70	38.57	0.30	0.18	1.16	0.17	7.72	4.57
Average	**263.13**	**15.64**	**0.29**	**0.08**	**1.17**	**0.07**	**7.30**	**1.93**
Case 3								
Group 1-10	271.20	18.78	0.23	0.03	1.21	0.08	5.79	0.68
Group 11-20	288.60	17.78	0.25	0.03	1.28	0.08	6.22	0.65
Group 21-30	287.00	10.70	0.23	0.02	1.28	0.05	5.77	0.45
Average	**282.27**	**8.67**	**0.23**	**0.01**	**1.26**	**0.04**	**5.93**	**0.31**
Case 4								
Group 1-10	331.50	22.50	0.26	0.02	1.47	0.10	6.55	0.57
Group 11-20	317.40	18.57	0.25	0.03	1.41	0.08	6.38	0.64
Group 21-30	303.10	22.83	0.24	0.03	1.35	0.10	6.20	0.78
Average	**317.33**	**11.64**	**0.25**	**0.01**	**1.41**	**0.05**	**6.38**	**0.34**
Case 5								
Group 1-10	282.40	21.24	0.26	0.05	1.26	0.09	6.50	1.19
Group 11-20	308.80	20.75	0.24	0.04	1.37	0.09	6.20	0.98
Group 21-30	303.20	29.11	0.25	0.04	1.35	0.13	6.45	1.08
Average	**298.13**	**12.84**	**0.25**	**0.02**	**1.33**	**0.06**	**6.38**	**0.55**