



Institute of Paper Science and Technology

HIGH-INTENSITY DRYING PROCESSES – IMPULSE DRYING

**PRODUCTION OF LINERBOARD ON A PILOT PAPER MACHINE,
SUBSEQUENT COMMERCIAL CONVERTING TRIALS AND PRELIMINARY
ECONOMIC ASSESSMENT**

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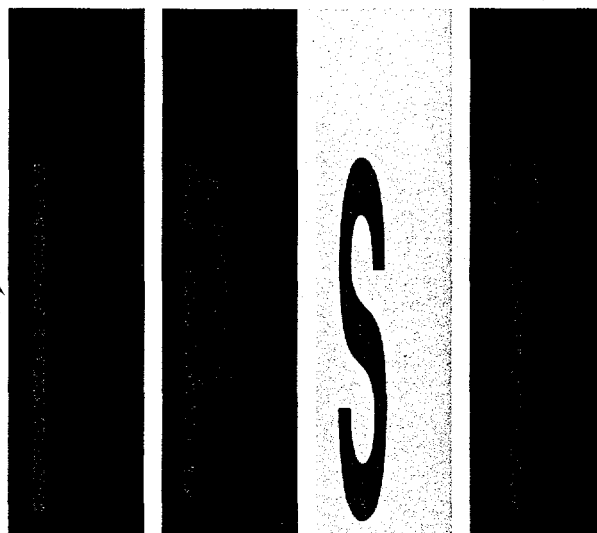
IPST Project 3595

REPORT 15

**A Final Report
to the
U. S. DEPARTMENT OF ENERGY
April 1999**

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Atlanta, Georgia

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PRODUCTION OF LINERBOARD ON A PILOT PAPER MACHINE, SUBSEQUENT
COMMERCIAL CONVERTING TRIALS AND PRELIMINARY ECONOMIC ASSESSMENT

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A Final Report

To the

U.S. DEPARTMENT OF ENERGY
Work Performed Under Contract DE-FG07-85CE40738

By

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April 1999

INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY
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Project 3595

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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/m² (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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2. Orloff, D. I., Patterson, T., Parviainen, P. M., "Opening the Operating Window of Impulse Drying - Part II. Pressure Differential as a Source Of Delamination," Tappi Journal 81(8):195-203 (August 1998).
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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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6. Soczka, E., personal communication, December 1998, Institute of Paper Science and Technology, Atlanta, Georgia.
7. Orloff, D. I., "Impulse Drying of Board Grades: An Emerging Technology," PaperAge, 114(12): 22-23 (December 1998).
8. Orloff, D.I., Challas, J., and Rudman, I., "Flexographic Printing of Linerboard," TAGA Proceedings, 1:277-303(1995).

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
2	381	SFWP	1050	205 to 262	n.a.	Dryness samples
				n.a.	10-45	Reel samples
					0 (open)	4 Reels produced
2	381	ID	1050	204 to 288	35	4 Reels produced
					n.a.	Dryness samples
					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, °C	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

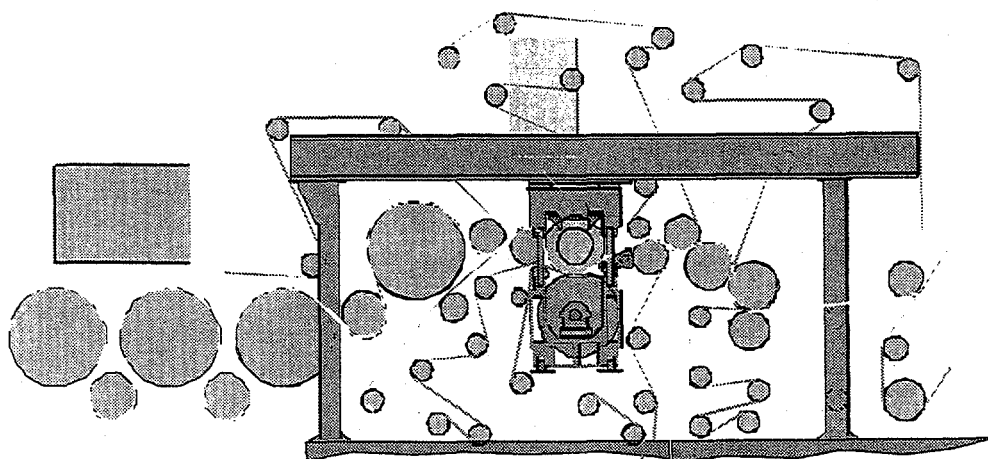


Figure B1. Press Section of the Pilot Paper Machine Showing the Impulse Dryer.

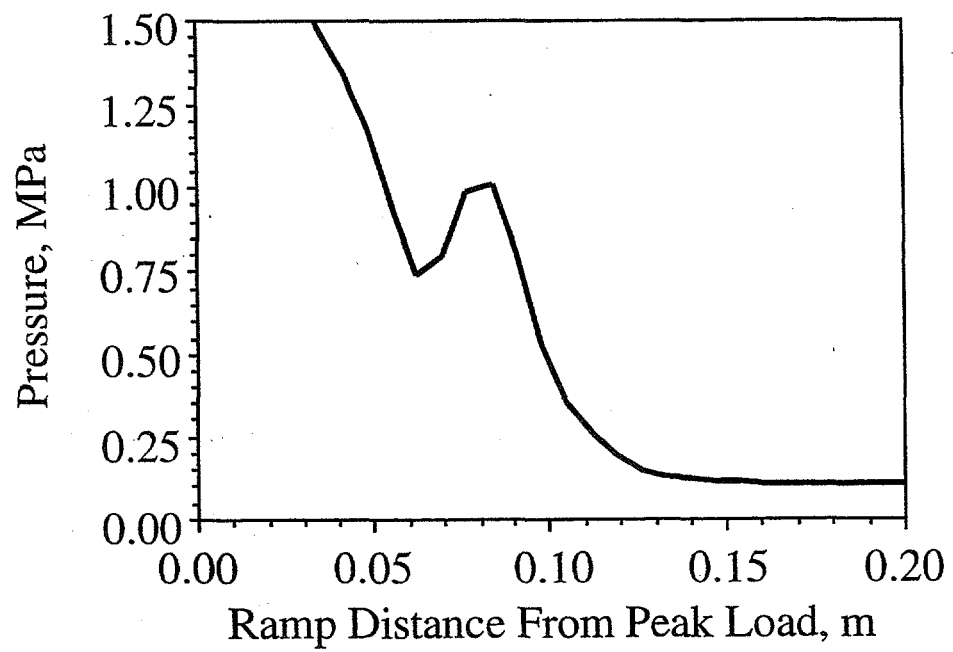


Figure B2. Ramp Pressure Profile.

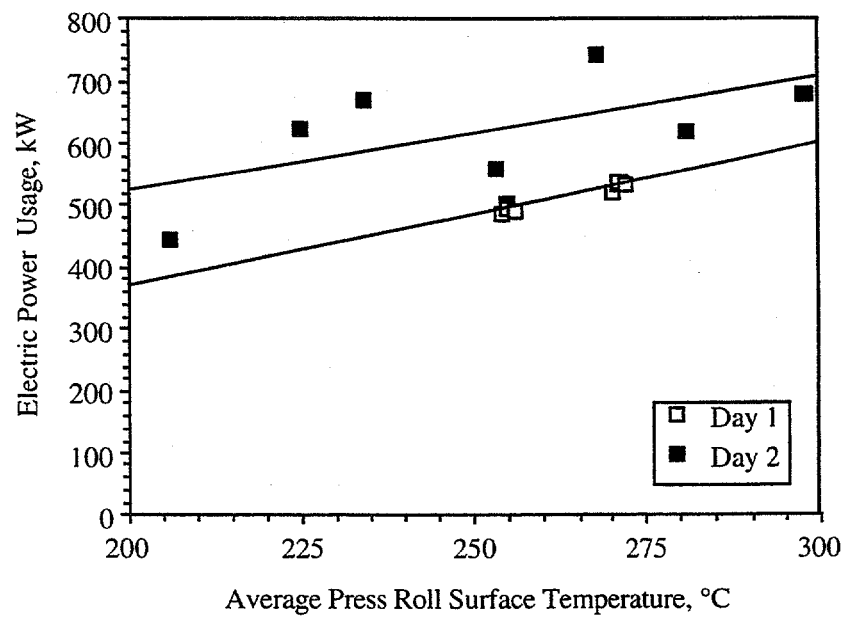


Figure B3. Electric Power Usage versus Average Press Roll Temperature.

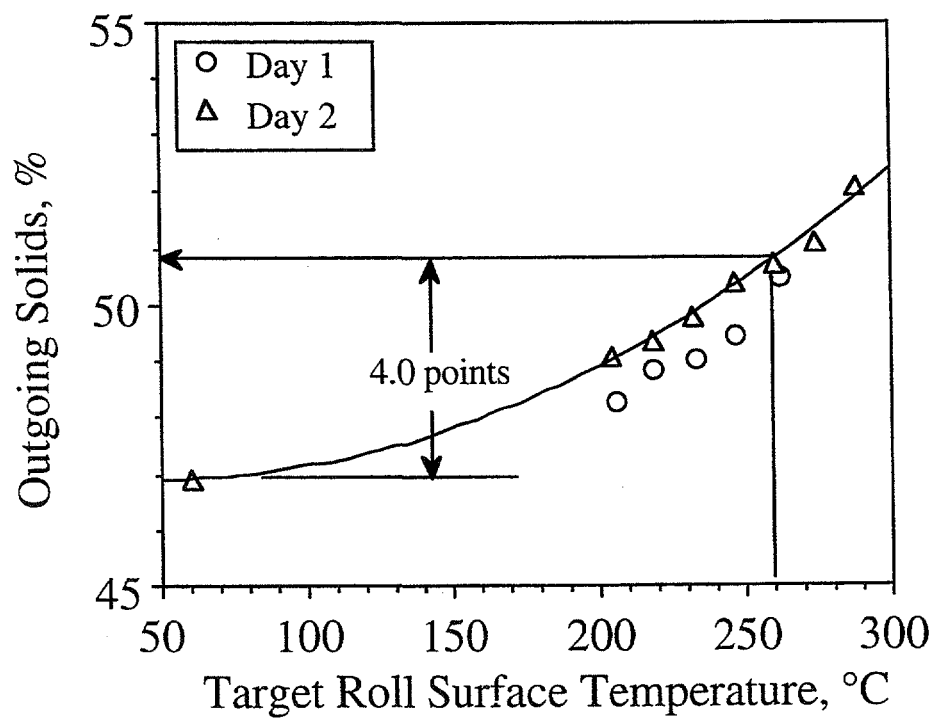


Figure B4. Outgoing Solids versus Target Roll Surface Temperature.

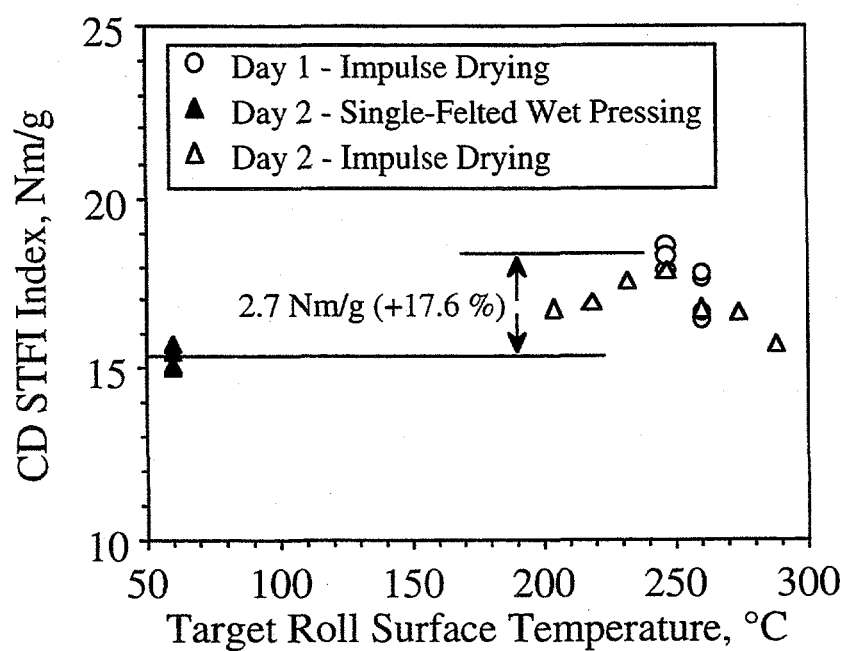


Figure B5. Cross-Directional STFI Compression Strength Index versus Target Roll Surface Temperature.

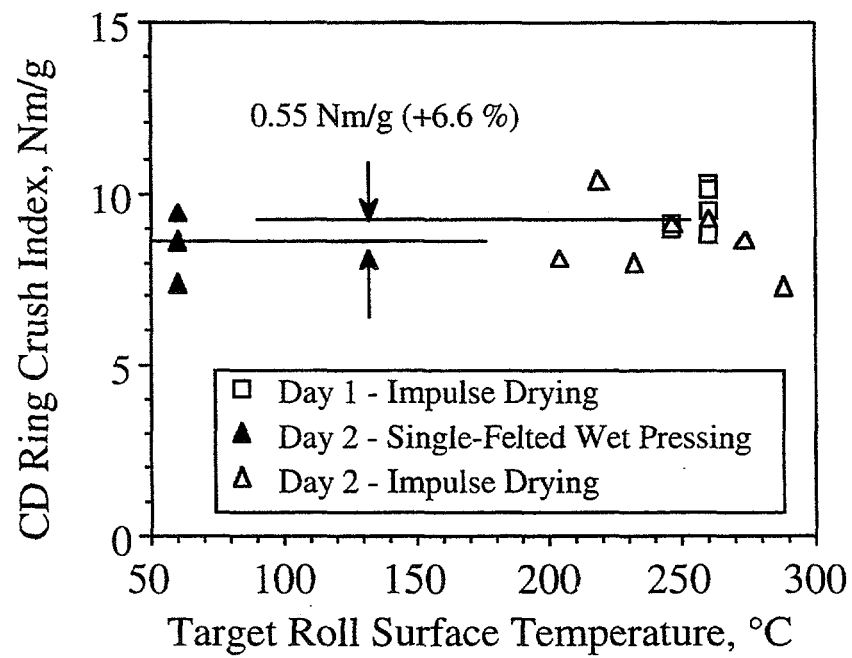


Figure B6. Cross-Directional Ring Crush Index versus Target Roll Surface Temperature.

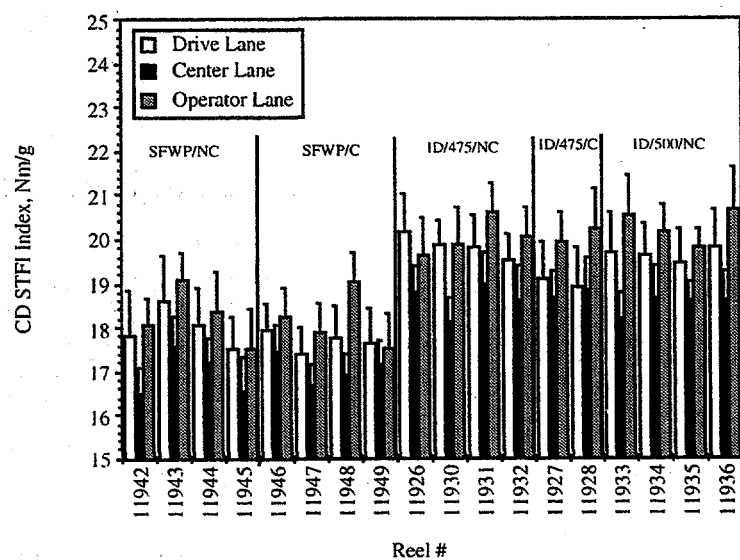


Figure B7. Cross-Directional STFI Index versus Reel Number

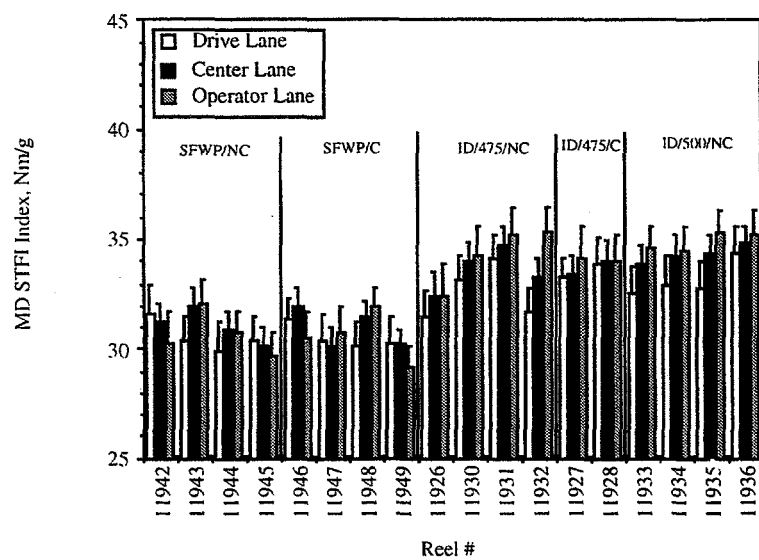


Figure B8. Machine-Directional STFI Index versus Reel Number

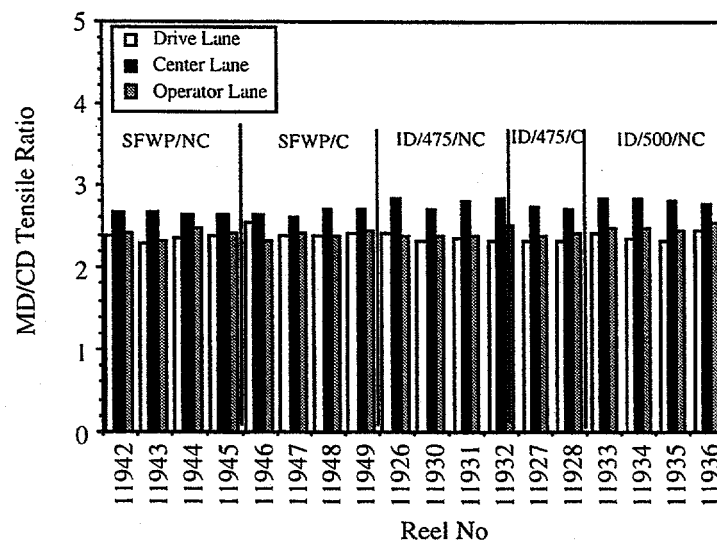


Figure B9. MD/CD Tensile Ratio Versus Reel Number

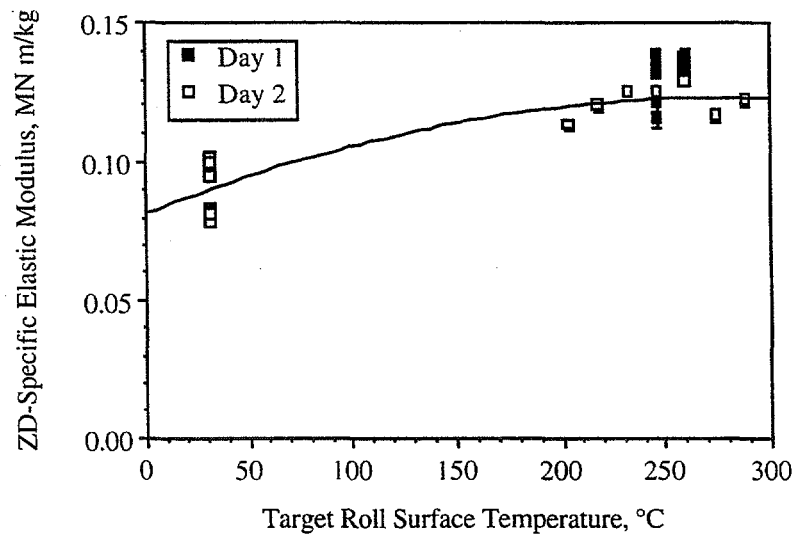


Figure B10. ZD- Specific Elastic Modulus versus Target Roll Surface Temperature.

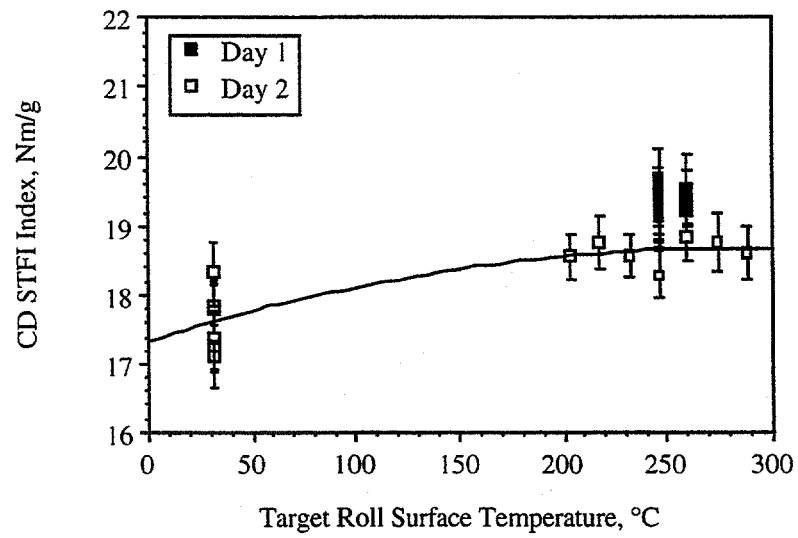


Figure B11. Cross-Directional STFI Compression Index versus Target Roll Surface Temperature.

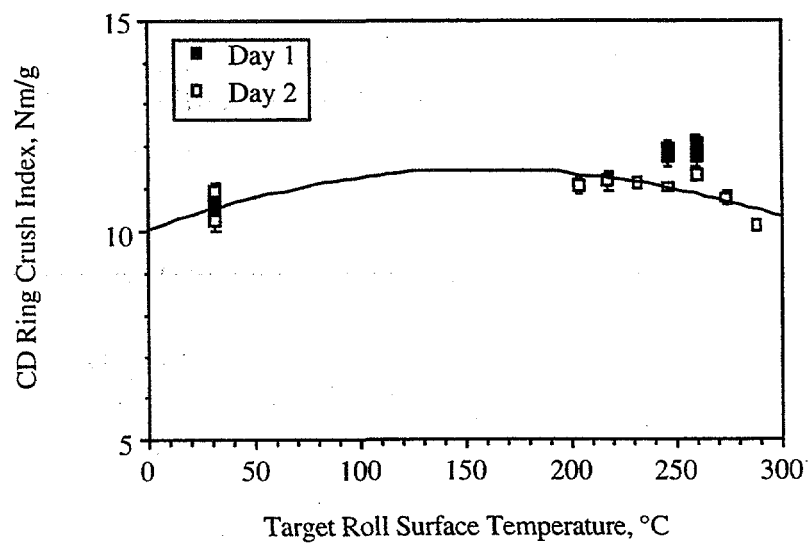


Figure B12. Cross-Directional Ring Crush Index versus Target Roll Surface Temperature.

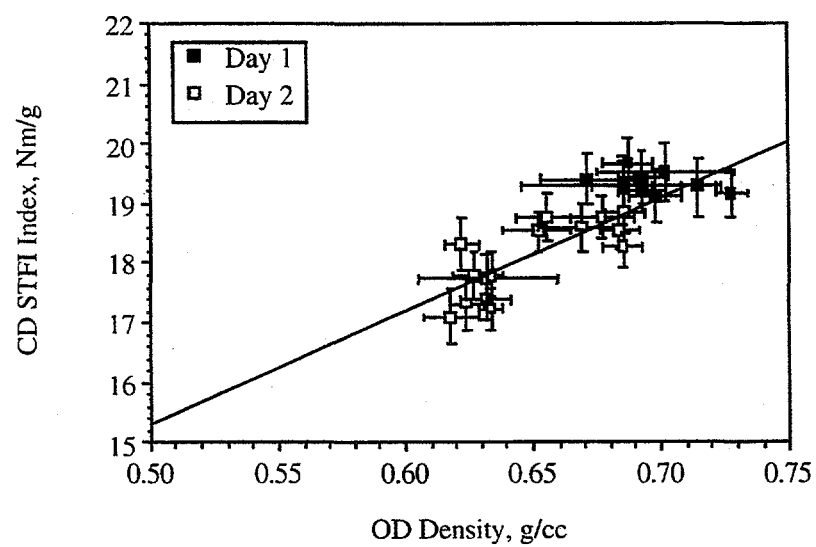


Figure B13. Cross-Directional STFI Compression Index versus OD Density.

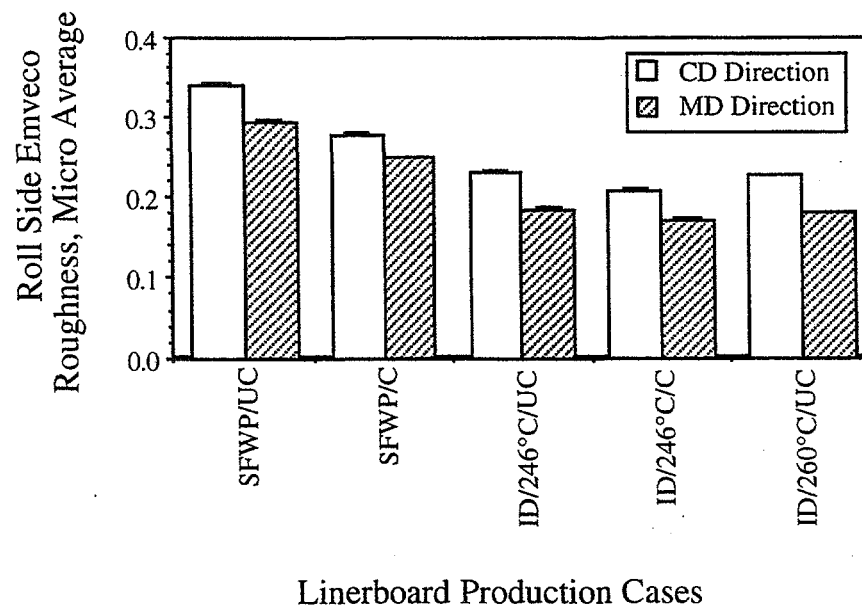


Figure B14. Micro Average Roll Side Emveco Roughness for Linerboard Production Cases.

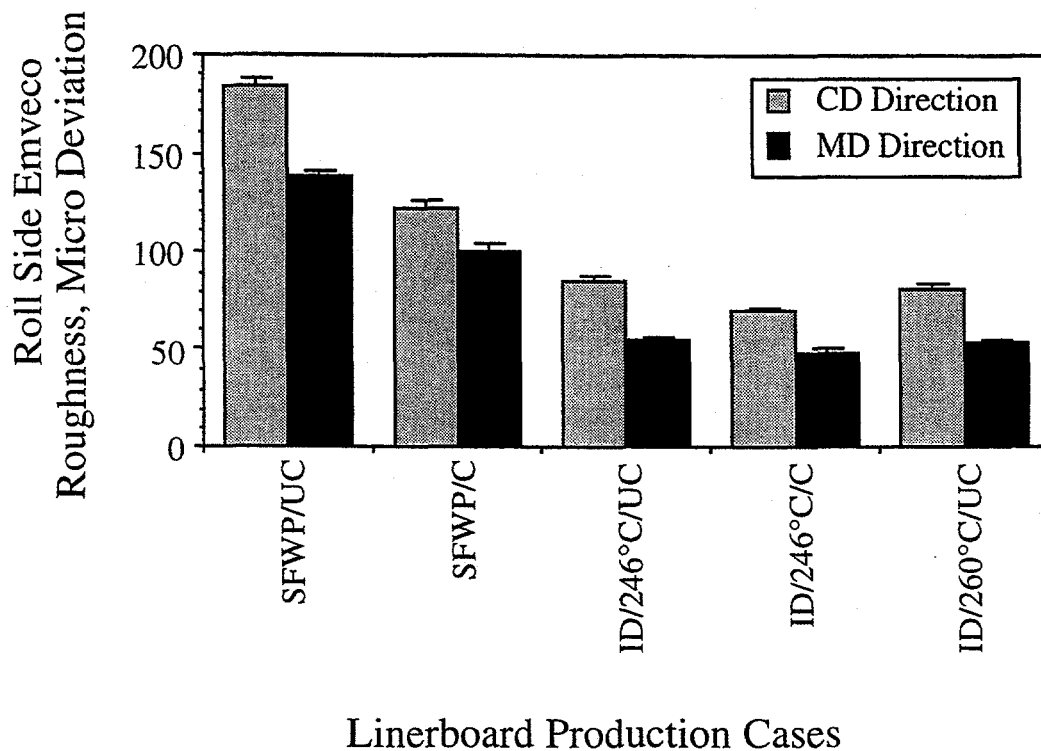


Figure B15. Micro Deviation Roll Side Emveco Roughness for Linerboard Production Cases.

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/m² (33#) kraft linerboard made on Beloit pilot paper machine. One set of 161 g/m² (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/m² (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 commercial 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 at 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,

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

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:

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

ECT Grades 38-60 lb/in:

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

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

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

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

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,

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

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,

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

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

Where,

D_x, D_y = 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/in²

T = Average linerboard thickness, in

H = Combined board thickness, in

E_{ym} = Young's modulus of the medium in the CD direction, lb/in²

I = Moment of inertia of the flute, in⁴/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,

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

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,

$$\Delta P = (\delta P / \delta L) \Delta L + (\delta P / \delta E_{xf}) \Delta E_{xf} + (\delta P / \delta E_{yf}) \Delta E_{yf} + (\delta P / \delta T) \Delta T + (\delta P / \delta H) \Delta H \quad \{8\}$$

Taking the partial derivatives,

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

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

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

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

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

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, °C	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 Properties Of The Liner And Medium

Case	O.D. Basis Weight, g/m ²	Soft Caliper, µm	OD STFI Index, Nm/g	OD 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	OD 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)
E_{xf} , MN/m or (lb/in ²)	360.5 (52292)	375.7 (54483)	15.2 (+2191)
E_{yf} , 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

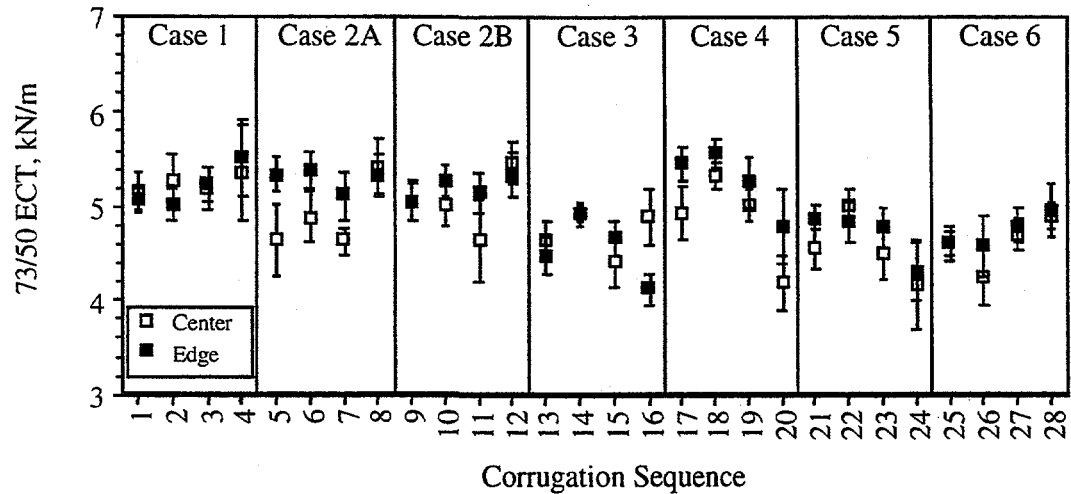


Figure C1. Edge Crush Test Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Sequence.

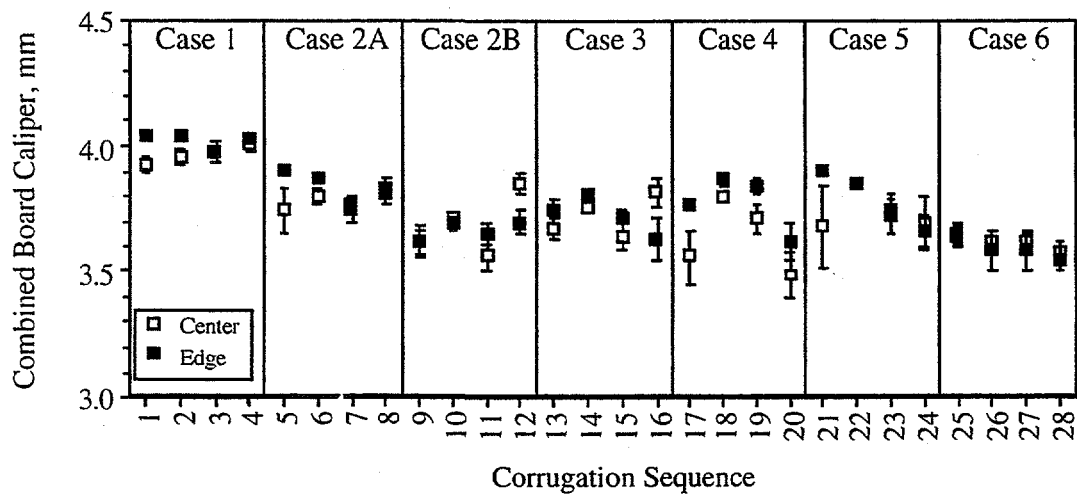


Figure C2. Caliper Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Sequence.

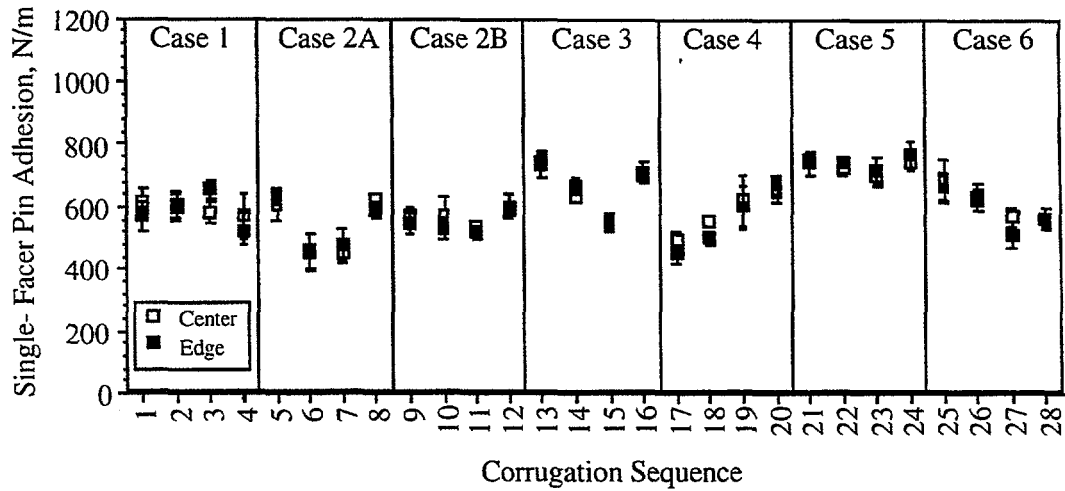


Figure C3. Single-Facer Pin Adhesion Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Sequence.

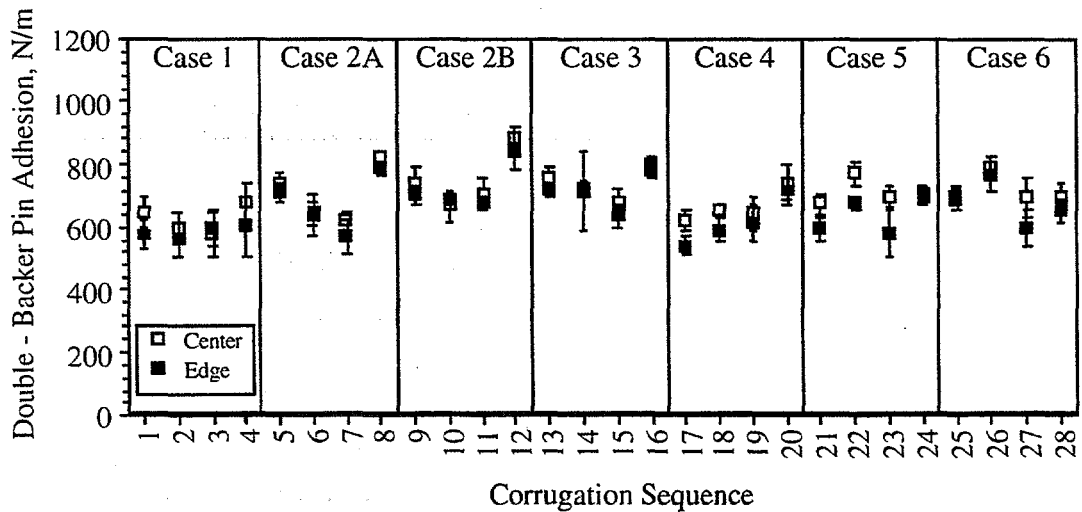


Figure C4. Double-Backer Pin Adhesion Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Sequence.

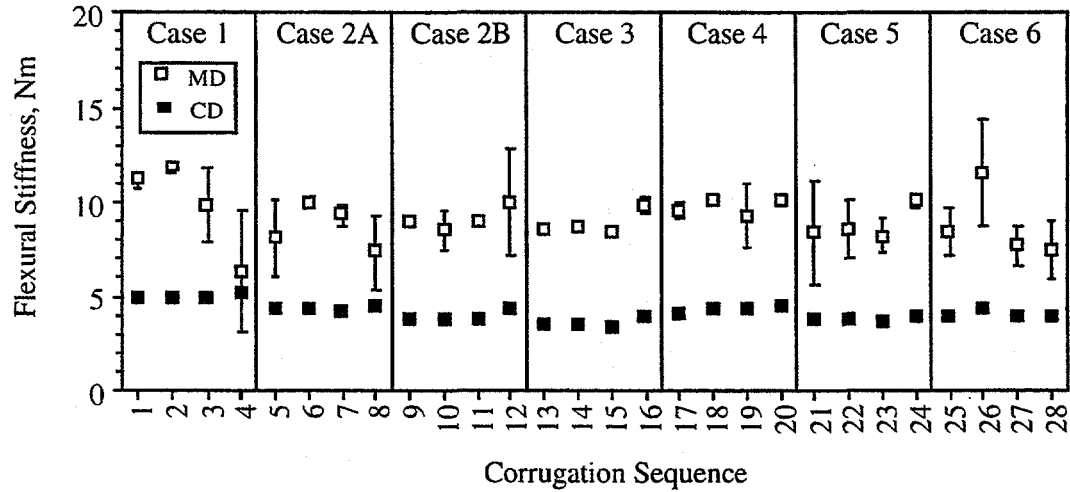


Figure C5. Flexural Stiffness Of Corrugated Board (As Measured In MD and CD Directions) Plotted Versus Corrugation Sequence.

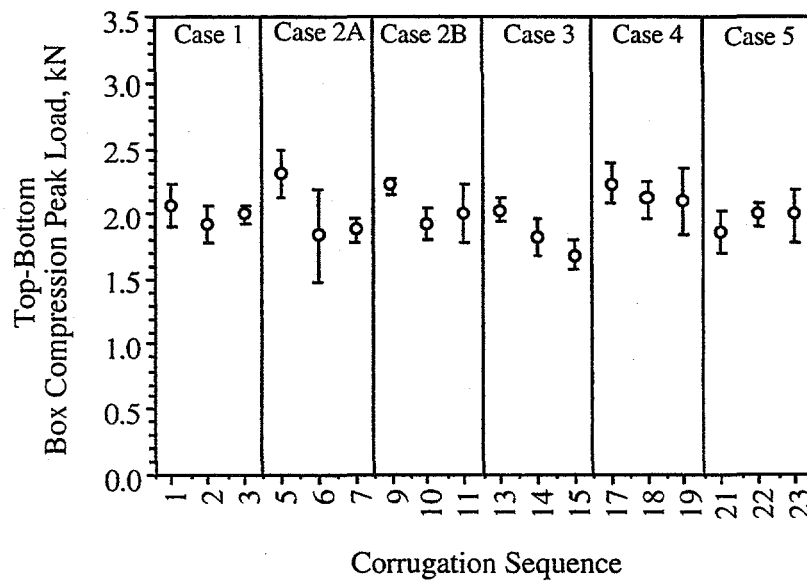


Figure C6. Top-To-Bottom Box Compression Peak Load Plotted Versus Corrugation Sequence.

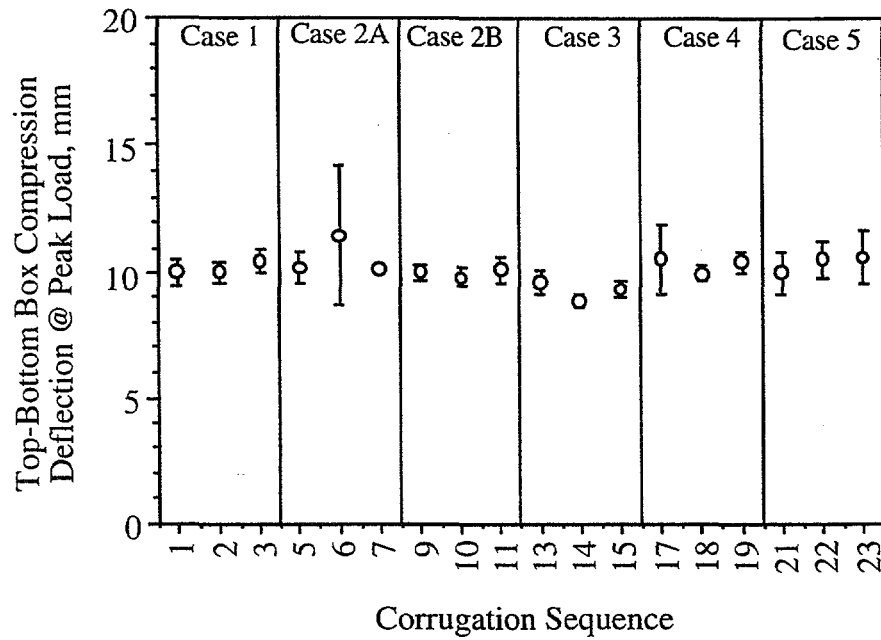


Figure C7. Top-To-Bottom Box Compression Deflection at Peak Load Plotted Versus Corrugation Sequence.

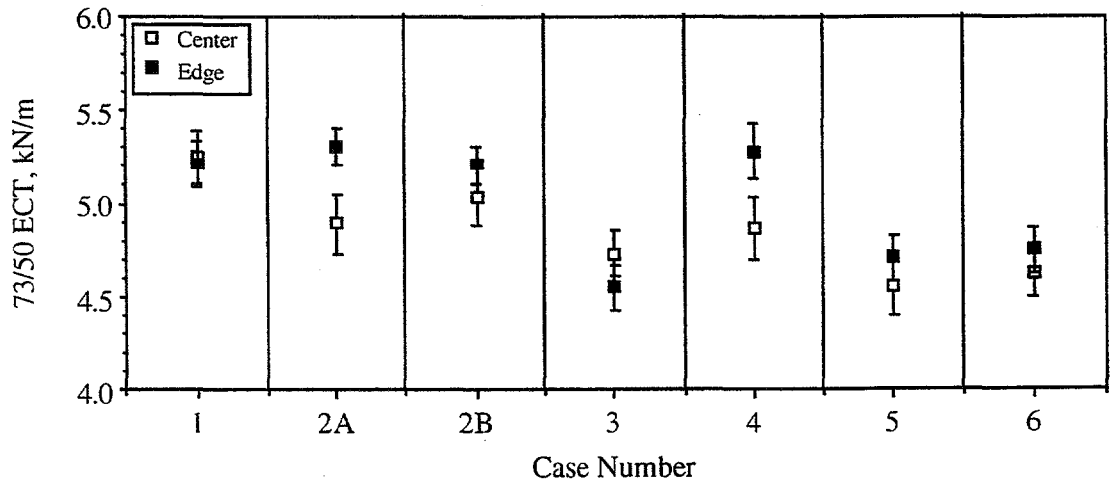


Figure C8. Edge Crush Test Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Case Number.

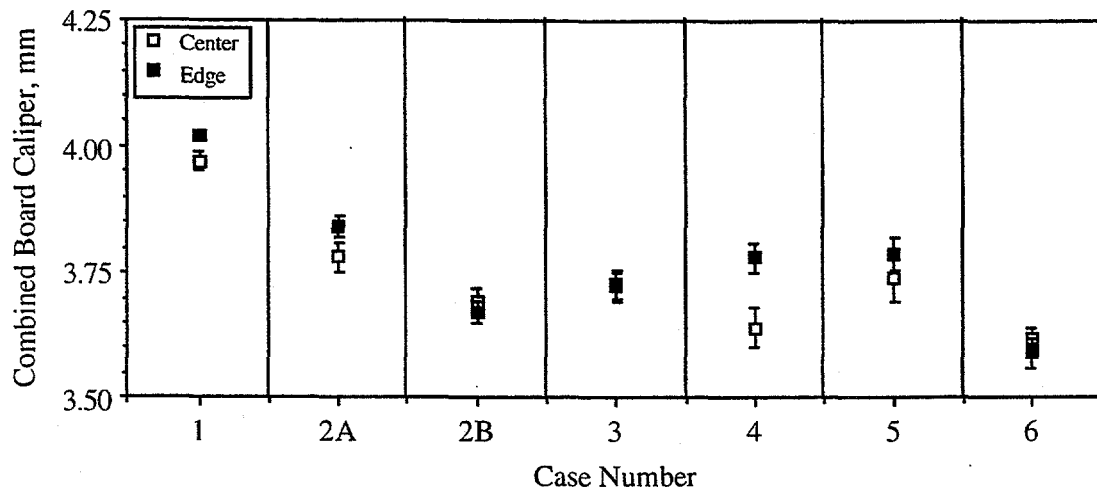


Figure C9. Caliper Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Case Number.

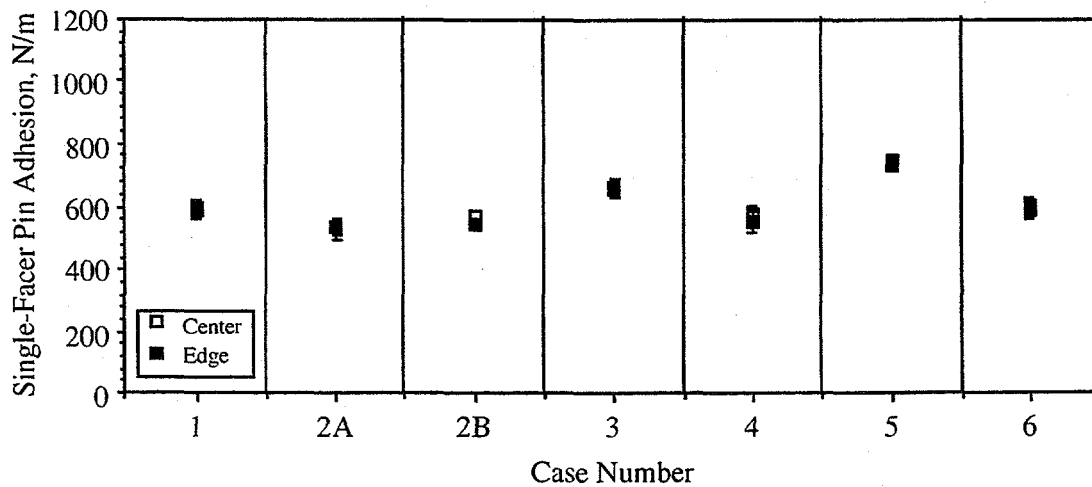


Figure C10. Single-Facer Pin Adhesion Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Case Number.

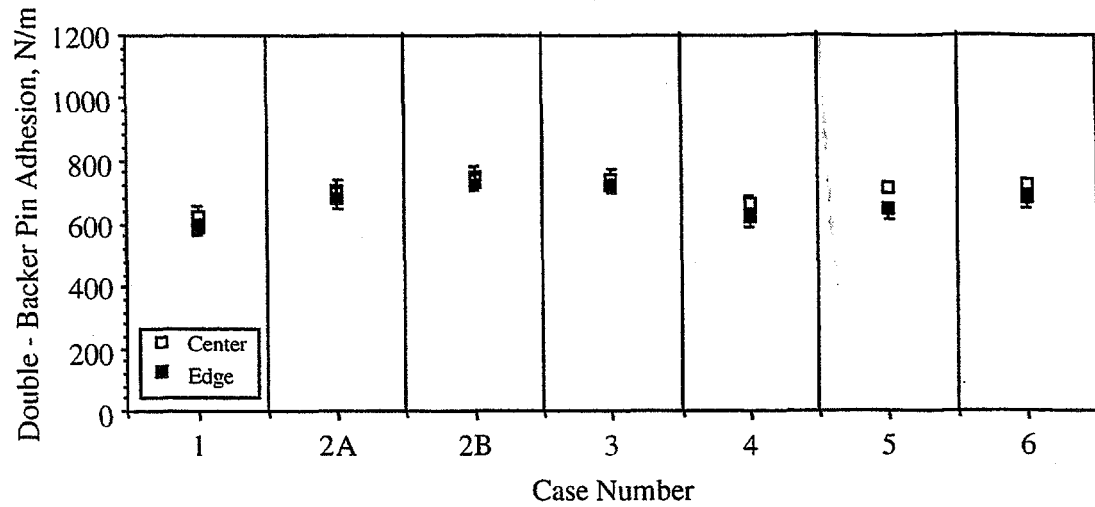


Figure C11. Double-Backer Pin Adhesion Of Corrugated Board (As Measured In The Center And On The Edges Of The Board) Plotted Versus Corrugation Case Number.

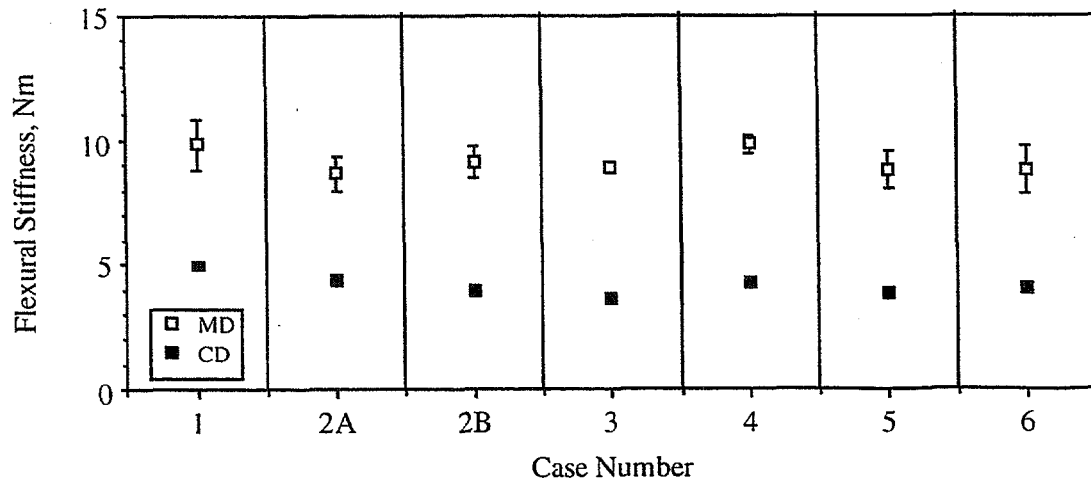


Figure C12. Flexural Stiffness Of Corrugated Board (As Measured In MD and CD Directions) Plotted Versus Corrugation Case Number.

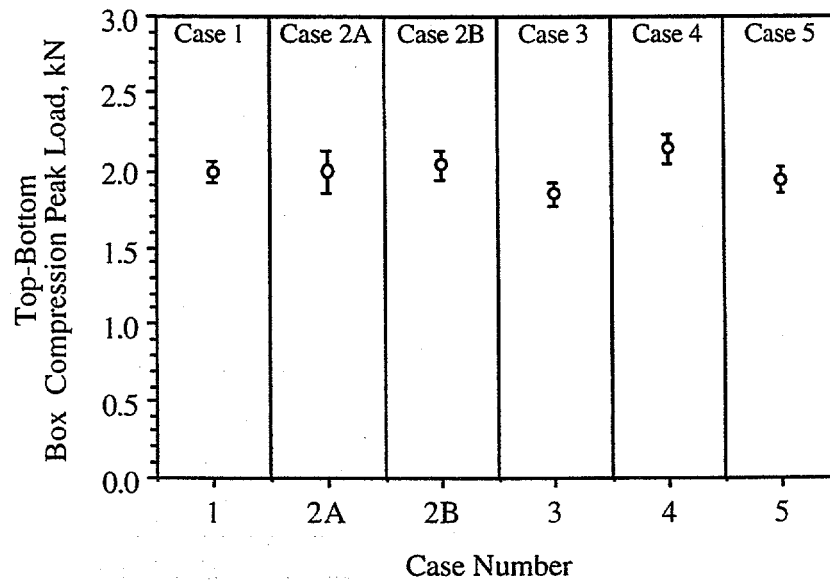


Figure C13. Top-To-Bottom Box Compression Peak Load Plotted Versus Corrugation Case Number.

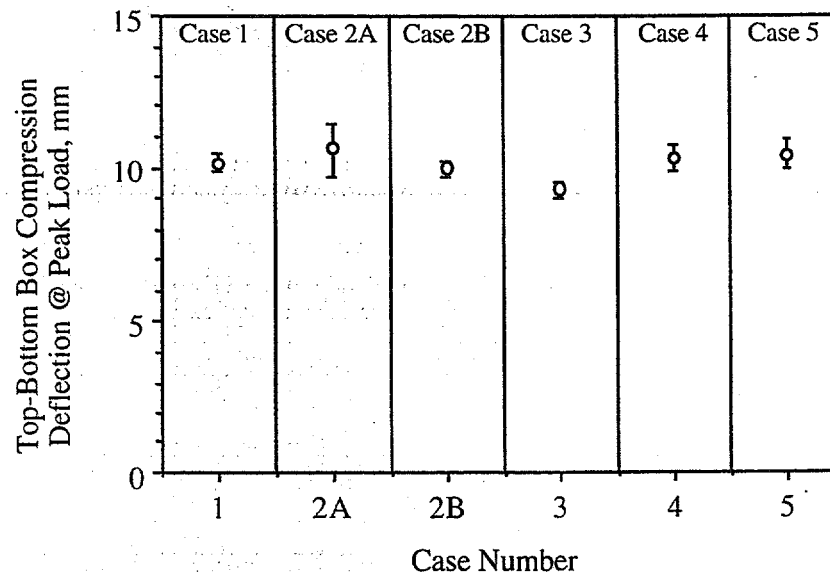


Figure C14. Top-To-Bottom Box Compression Deflection at Peak Load Plotted Versus

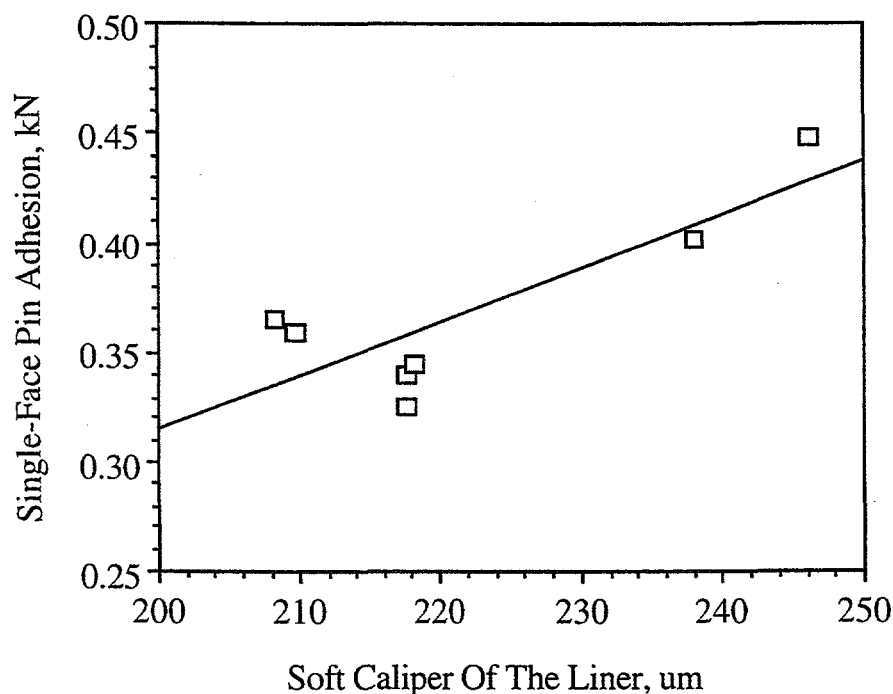


Figure C15. Single-Face Pin Adhesion Versus Linerboard Soft Caliper.

D. ECONOMICS

D1.) Summary

In September 1998 the Institute and Beloit Corporation were successful in producing 161 g/m² (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/m² (**OBWF** = 30.7 lb/1000 ft²). The basis weight at the reel is calculated from the reel solids and o.d. basis weight as **RBWM** = 158 g/m² (**RBWF** = 32.3 lb/1000 ft²).

$$\begin{aligned} \text{OBWF} &= 0.20482 (\text{OBWM}) & \{1\} \\ \text{RBWF} &= 100 (\text{OBWF})/(\text{RS}) & \{2\} \\ \text{RBWM} &= 100 (\text{OBWM})/(\text{RS}) & \{3\} \end{aligned}$$

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.

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

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.

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

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 $C1 = \$0.03/\text{kW-hr}$, pulp costs $C3 = \$200/\text{o.d. ton}$ and steam costs $C2 = \$0.01/\text{kW-hr}$ ($C2' = \$2.83/\text{million Btu}$).

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

The paper-machine speed was also entered. For the example, the dryer limited machine speed was taken as $S = 600 \text{ m/min}$.

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

$$We = [\{ (1 - (\%S_{in}/100)) / (\%S_{in}/100) \} - \{ (1 - (\%S_{out}/100)) / (\%S_{out}/100) \}] (OBWM) \quad \{7\}$$

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

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

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

$$SEU = H_{fg} (SU) \quad \{10\}$$

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

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

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

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

Also shown in Table 3-2 are the pulp usage, $PU = 0.0154 \text{ OD ton}/1000 \text{ ft}^2$ and pulp costs, $CP = \$3.07 / 1000 \text{ ft}^2$, 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 $Fave = 669 \text{ ml CSF}$. The refining energy is then estimated as $Re = 71 \text{ kW-hr/ton}$ at the reel ($RER = 0.079 \text{ kW-hr/kg}$ 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 $CTEAF = \$0.16 / 1000 \text{ ft}^2$ 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/m² (**OBWFd** = 27.7 lb/1000 ft²) and the basis weight at the reel as **RBWMd** = 142 g/m² (**RBWFd** = 29.1 lb/1000 ft²).

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/m², 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.

$$Wed = [\{ (1 - (\%Sind/100)) / (\%Sind/100) \} - \{ (1 - (\%Soutd/100)) / (\%Soutd/100) \}] (OBWMd) \quad \{32\}$$

$$Sd = 0.06 WE / (Wed) (W) \quad \{33\}$$

Given production at the reel of **Prd** = 66,633 kg/hr (**PRd** = 468,900 m²/hr), steam usage may be calculated as **SEURd** = 0.745 kW-hr/kg at the reel.

$$SEURd = 0.0002778 SEU / (Prd) \quad \{34\}$$

$$Prd = 0.06 Sd (W) (RBWMd) \quad \{35\}$$

$$PRd = 1000 Prd / (RBWMd) \quad \{36\}$$

Pulp usage may then be calculated as **Pud** = 0.0138 o.d. ton/1000 ft² and the cost of that pulp may be calculated as **CPd** = \$2.77/1000 ft².

$$Pud = 0.00010241 (OBWMd) \quad \{37\}$$

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

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/m² 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/m² (**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 ft² 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 ft²), 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 ft². 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 ft² of product produced. On that basis, Figure D2 shows that the energy cost penalty should range from \$0.05 to \$0.08 per 1000 ft² 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 ft².

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 ft² of production. For a machine producing 121millionft²/day, operating cost savings of between \$2,400 to \$30,000/day could be realized.

D5.) Acknowledgements

The authors would like to thank the Member Companies of the Institute of Paper Science and Technology, the Beloit Corporation, and the U.S. Department of Energy (through Grant No. DOE/CE/40738) for supporting this research. The author would also like to thank David White of Union Camp Corporation for his contributions to this work.

Table D1. Input Data: Conventional

Reel State:	Solids @ Reel	Width @ Reel
(1a)	RS, %	W, m
	95	10

Total Sheet:	o.d. Basis Wt.	o.d. Basis Wt.,	Reel Basis Wt.,	Reel Basis Wt.,
(1b)	OBWM, g/m²	OBWF, lbm/1000ft²	RBWF, lbm/1000ft²	RBWM, g/m²
	150	30.7	32.3	158

Sheet Structure:	Ply Number	Freeness,	OD Basis Wt.,	OD Basis Wt.,
(1c)	PLY(i)	F(i), ml CSF	%BW(I), %	BW(i), lbm/1000ft²
	1	669	15	4.6
	2	669	85	26.1

Drying Input Data:	Solids	Solids	Steam/Water	Steam Pressure	Latent Heat
(1d)	Into Dryer	Out Of Dryer	Use Ratio		Of Steam
	%Sin, %	%Sout, %	R	P, bar	Hfg, kJ/kg
	47	95	1.5	7.74	2051

Cost Input Data:	Electricity	Steam	Steam	Pulp
(1e)	Cost	Cost	Cost	Cost
	C1, \$/kW-hr	C2, \$/kW-hr	C2', \$/million Btu	C3, \$/o.d.Ton
	0.030	0.01	2.83	200

Dryer Limited	Speed @ Reel
PM Conditions:	S, m/min
(1f)	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)	Solids @ Reel RS, %	Width @ Reel W, m	(3b)	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/m² 124	Speed @ Reel: Table 4b	Speed @ Reel Sd, m/min 781
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Steam Used By Dryer Section: (4c)	Steam Used SU, kg/hr 87077	Steam Energy Used SEU, kJ/hr 178601144	Steam Energy Used SEURd, kW-hr/kg @ Reel 0.745
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Paper Production Rate: (4d)	Paper Produced @ Reel Prd, kg/hr 66633	Paper Produced @ Reel PRd, m²/hr 468900	Pulp Usage Pud, OD Ton/1000ft² 0.0138	Pulp Cost CPd, \$/1000 ft² 2.77
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Refining Energy: (4e)	Average Freeness Faved, ml CSF 613	Refining Energy Use Red, kW-hr/Ton @ Reel 98	Refining Energy Use REURd, kW-hr/kg @ Reel 0.108
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I.D. Energy: (4f)	Roll Energy Transfer RETd, kJ/m² 97	Roll Heating Power Use RHPud, kW-hr/hr 12606	Roll Heating Power RHPAd, kW-hr/m² 0.0269	Roll Heating Power RHPMd, kW-hr/kg @ Reel 0.189
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Cost Of Energy: (4g)	Cost Of Electric Power CELd, \$/kg @ Reel 0.0089	Cost Of Steam CSTd, \$/ kg @ Reel 0.0074	Total Energy Cost CTEd, \$/ kg @ Reel 0.0164	Total Energy Cost CTETd, \$/ Ton @ Reel 14.85
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Cost Of Energy: (4h)	Cost Of Electric Power CELAd, \$/m² @ Reel 0.0013	Cost Of Steam CSTAd, \$/m² @ Reel 0.0011	Total Energy Cost CTEAd, \$/m² @ Reel 0.0023	Total Energy Cost CTEAFd, \$/1000 ft² @ Reel 0.22
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Variable Costs: (4i)	Variable Energy Costs VECOSTd, \$/day 26,175	Variable Pulp Costs VPCOSTd, \$/day 334,934	Total Variable Costs TVCOSTd, \$/day 361,109
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Table D5. Overview of Input and Output Data

Conventional Data		Input Data	Conventional		Output Data			
Conventional	Solids @ Reel, %	95	o.d. Basis Wt., lbm/1000 ft^2 Reel Basis Wt., lbm/1000 ft^2 Reel Basis Wt., gsm o.d. Basis Wt. Layer 1, g/m^2 o.d. Basis Wt. Layer 2, g/m^2 Latent Heat of Steam, kJ/kg Steam Cost, \$/MMBtu	Impulse Drying Solids Into Dryer, % o.d. Basis Wt., lbm/1000 ft^2 Reel Basis Wt., lbm/1000 ft^2 Reel Basis Wt., gsm o.d. Basis Wt. Layer 1, g/m^2 o.d. Basis Wt. Layer 2, g/m^2 Latent Heat of Steam, kJ/kg Steam Cost, \$/MMBtu	Output Data 50.8 27.7 29.1 142 4.1 23.5 2051 2.83			
	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	Water Evaporated, g/m^2 Water Evaporated, kg/hr Steam Used, kg/hr Steam Energy Used, kJ/hr Steam Energy Used, kW-hr/kg @ Reel Paper Produced @ Reel, kg/hr Paper Produced @ Reel, m^2/hr Pulp Usage, o.d. Ton/1000 ft^2 Pulp Cost, \$/1000 ft^2 Average Freeness, ml CSF Refining Energy Used, kW-hr/ton @ Reel Refining Energy Used, kW-hr/kg @ Reel Cost of Electric Power, \$/kg @ Reel Cost of Steam, \$/kg @ Reel Total Energy Cost, \$/kg @ Reel Total Energy Cost, \$/ton @ Reel	Impulse Drying Water Evaporated, g/m^2 Speed @ Reel, m/min Steam Used, kg/hr Steam Energy Used, kJ/hr Steam Energy Used, kW-hr/kg @ Reel Paper Produced @ Reel, kg/hr Paper Produced @ Reel, m^2/hr Pulp Usage, o.d. Ton/1000 ft^2 Pulp Cost, \$/1000 ft^2 Average Freeness, ml CSF Refining Energy Used, kW-hr/ton @ Reel Refining Energy Used, kW-hr/kg @ Reel Roll Energy Transfer, kJ/m^2 Roll Heating Power Use, kW-hr/hr Roll Heating Power, kW-hr/m^2 Roll Heating Power, kW-hr/kg @ Reel	Output Data 124 781 87077 178601144 0.745 66633 468900 0.0138 2.77 613 98 0.108 96.8 12606 0.0269 0.189				
Electricity Cost, \$/kW-hr	0.03							
Steam Cost, \$/kW-hr	0.01							
Speed @ Reel, m/min	600							
Impulse Drying Data								
Basis Wt. Reduction, %	10				Cost of Electric Power, \$/m^2 @ Reel Cost of Steam, \$/m^2 @ Reel Total Energy Cost, \$/m^2 @ Reel Total Energy Cost, \$/1000 ft^2 @ Reel	Output Data 0.0037 0.00138 0.00175 0.163		
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 Variable Pulp Costs, \$/day Total Variable Costs, \$/day Impulse Drying Variable Energy Costs, \$/day Variable Pulp Costs, \$/day Total Variable Costs, \$/day		Percent Increase In Variable Costs, % 20.03				
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							

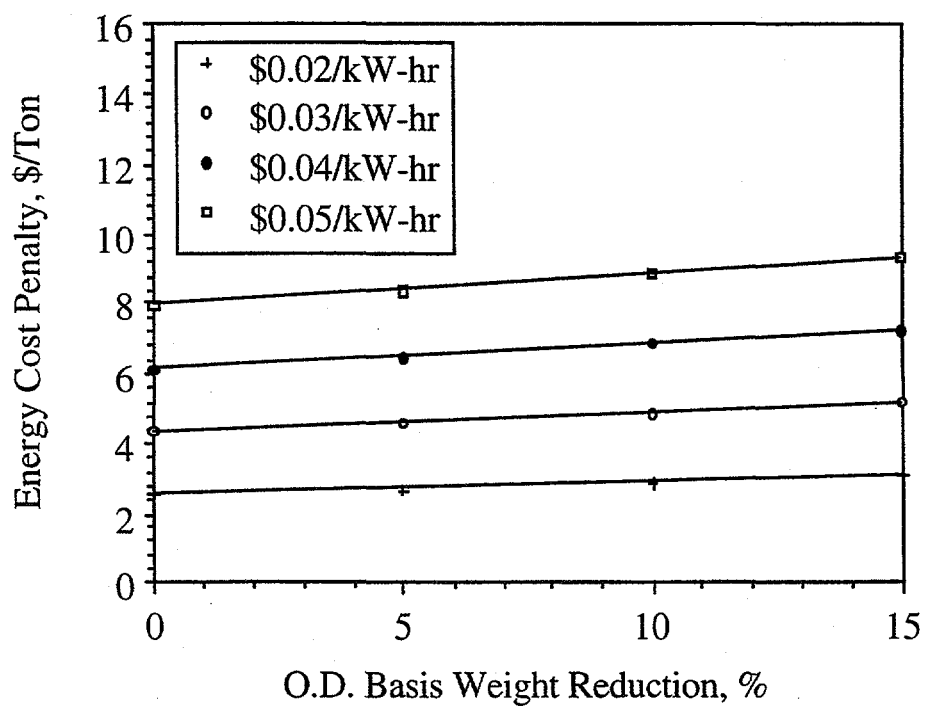


Figure D1. Energy Cost Penalty (Tonnage Basis) Versus O. D. Basis Weight Reduction.

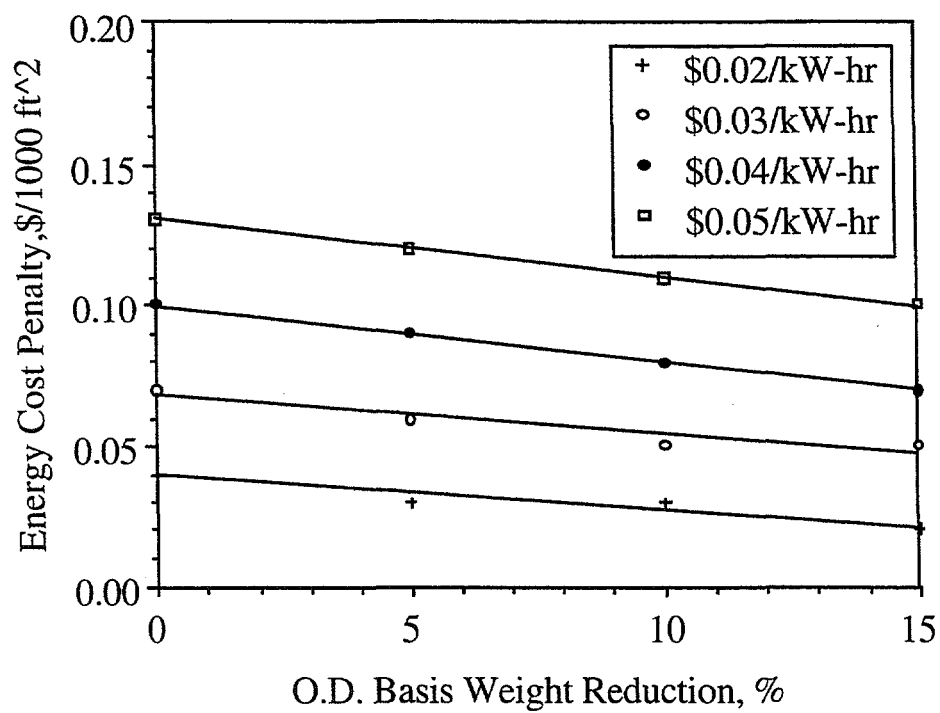


Figure D2. Energy Cost Penalty (Area Basis) Versus O.D. Basis Weight Reduction.

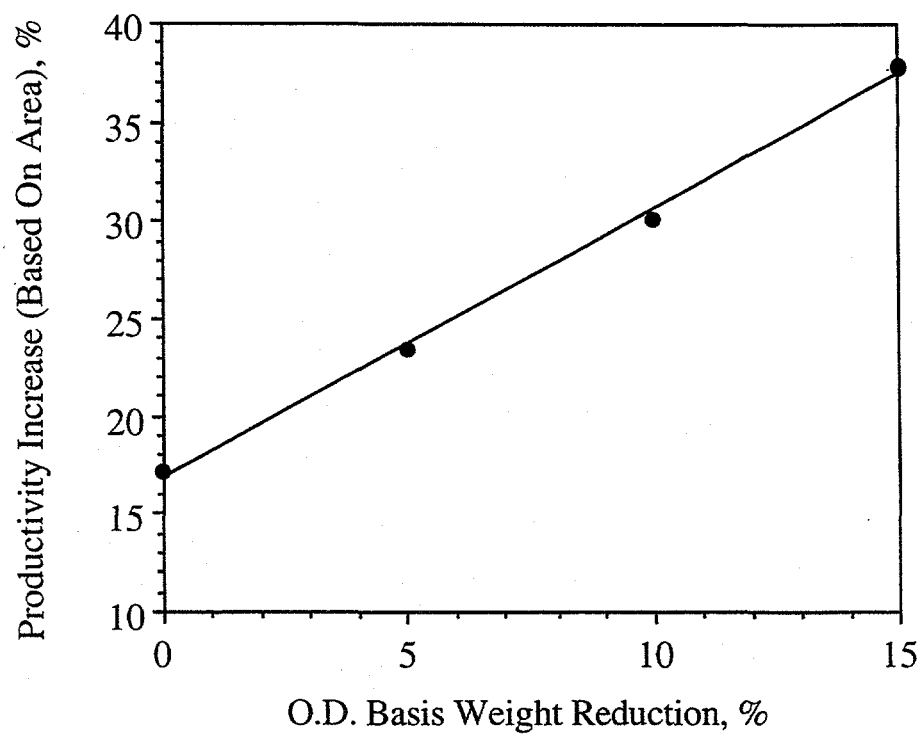


Figure D3. Productivity Increase (Area Basis) Versus O. D. Basis Weight Reduction.

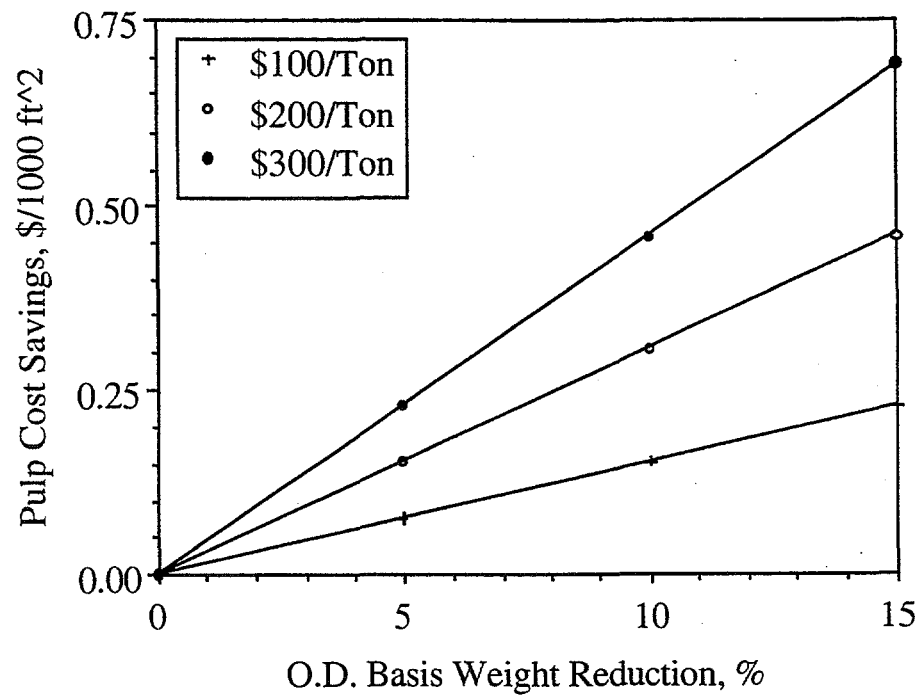


Figure D4. Pulp Cost Savings (Area Basis) Versus O. D. Basis Weight Reduction.

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 compression 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/cm ³)	Scott Bond (kJ/m ²)	MD STFI Index (N*/m/g)	CD STFI Index (N*/m/g)	CD STFI (lbf/in)
Case 5 Wet Press No Calender	11942	46.91	162.2	33.23	0.571	0.153	29.10	15.70	14.54
	11943	46.91	159.4	32.66	0.566	0.147	31.80	15.50	14.11
	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 Wet Press 35 KN/m Calender	11946	46.91	156.2	32.00	0.608	0.130	30.70	15.60	13.91
	11947	46.91	160.9	32.97	0.603	0.141	31.00	16.50	15.16
	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 2 246 °C Roll Temp No Calender	11926	49.47	158.8	32.54	0.615	0.168	33.69	18.60	16.87
	11930	49.47	163.0	33.40	0.640	0.174	33.14	17.89	16.65
	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 6 246 °C Roll Temp 35 KN/m Calender	11927	49.47	157.1	32.19	0.670	0.164	34.60	17.67	15.85
	11928	49.47	159.6	32.70	0.680	0.177	35.40	18.41	16.78
	Average	49.47	158.4	32.44	0.675	0.171	35.00	18.04	16.31
	11933	50.47	156.1	31.98	0.611	0.183	35.31	16.42	14.64
	11934	50.47	160.1	32.80	0.616	0.177	33.49	17.60	16.09
Case 4 260 °C Roll Temp 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
	11950	49.08	162.3	33.25	0.634	0.153	31.81	16.73	15.50
	11951	49.35	159.8	32.74	0.634	0.156	33.12	16.94	15.46
204 °C Roll Temp 218 °C Roll Temp 232 °C Roll Temp 246 °C Roll Temp 260 °C Roll Temp 274 °C Roll Temp 288 °C Roll Temp	11952	49.79	159.5	32.68	0.626	0.153	32.13	17.54	15.97
	11953	50.38	161.2	33.03	0.627	0.160	30.28	17.86	16.44
	11954	51.06	164.1	33.62	0.640	0.149	32.75	16.63	15.58
	11955	51.06	164.1	33.62	0.640	0.149	32.75	16.63	15.58
	11956	52.05	162.7	33.34	0.630	0.162	30.05	15.73	14.61
WP - 43.8 KN/m Cal. WP - 37.1 KN/m Cal. WP - 10.5 KN/m Cal. WP - 28.7 KN/m Cal. WP - 19.8 KN/m Cal.	11937	162.7	162.7	33.34	0.637	0.145	30.1	16.0	14.87
	11938	161.4	161.4	33.07	0.628	0.143	29.5	17.2	15.85
	11939	161.5	161.5	33.09	0.588	0.145	30.8	16.3	15.03
	11940	159.6	159.6	32.70	0.585	0.143	31.3	15.9	14.49
	11941	158.0	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 Wet Press No Calendar	11942	2000	1985	>386	>386	9.8	1210	11.9	9.4
	11943	1935	1985	>386	>386	9.9	1210	11.9	8.6
	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 Wet Press 35 KN/m Calendar	11946	1370	1245	>383	>380	10.2	1175	11.7	8.4
	11947	1410	1380	>378	377	9.8	1180	11.7	8.3
	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 2 246 °C Roll Temp No Calendar	11926	1650	2090	384	>386	24.5		12.7	9.0
	11930	1500	2240	>386	>386	24.9		14.1	9.0
	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 6 246 °C Roll Temp 35 KN/m Calendar	11927	1110	1370	322	385	26.4		11.5	9.5
	11928	910	1450	331	380	26.6		13.4	7.5
	Average	1010	1410	326.5	382.5	26.5		12.5	8.5
	11933	1330	2180	>386	>386	24.7		12.8	10.3
	11934	1430	1830	>386	>386	23.8		12.2	8.8
Case 4 260 °C Roll Temp No Calendar	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
	11950	1685	2020	>386	>386	16.4	745	11.3	8.1
	11951	1690	2060	>386	>386	17.3	715	12.4	10.4
204 °C Roll Temp 218 °C Roll Temp 232 °C Roll Temp 246 °C Roll Temp 260 °C Roll Temp 274 °C Roll Temp 288 °C Roll Temp	11952	1525	2095	>386	>386	19.1	615	12.8	8.0
	11953	1340	2055	>386	>386	18.3	640	12.7	9.1
	11954	1560	2110	>386	>386	17.1	655	11.7	9.3
	11955	1560	2110	>386	>386	17.1	690	11.1	8.7
	11956	1530	2165	>386	>386	19.0	635	11.7	7.3
WP - 43.8 KN/m Cal. WP - 37.1 KN/m Cal. WP - 10.5 KN/m Cal. WP - 28.7 KN/m Cal. WP - 19.8 KN/m Cal.	11937	1160	1150	362	370	12.7	955	11.1	7.5
	11938	1265	1355	372	>383	12.2	1025	11.3	8.4
	11939	1805	1840	>386	>386	10.7	1140	12.4	9.2
	11940	1900	1810	>386	>386	10.9	1105	13.3	10.0
	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 Wet Press No Calendar	11942	2.59	66.65	24.08	2.77
	11943	2.32	66.00	23.78	2.77
	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 Wet Press 35 KN/m Calendar	11946	2.47	68.45	24.11	2.84
	11947	2.89	70.10	24.98	2.81
	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 2 246 °C Roll Temp No Calendar	11926	3.17	79.72	28.23	2.82
	11930	3.03	77.56	26.78	2.90
	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 6 246 °C Roll Temp 35 KN/m Calendar	11927	3.25	77.85	28.50	2.73
	11928	3.02	79.48	28.27	2.81
	Average	3.14	78.67	28.39	2.77
	11933	3.05	81.08	29.32	2.77
Case 4 260 °C Roll Temp No Calendar	11934	2.89	77.44	26.78	2.89
	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
	11950	2.72	72.20	26.50	2.72
204 °C Roll Temp 218 °C Roll Temp 232 °C Roll Temp 246 °C Roll Temp 260 °C Roll Temp 274 °C Roll Temp 288 °C Roll Temp	11951	2.70	74.60	27.44	2.70
	11952	2.90	69.18	26.41	2.62
	11953	2.84	72.91	25.08	2.91
	11954	3.14	74.38	26.93	2.76
	11955	2.82	72.57	26.34	2.75
	11956	2.80	77.23	25.78	3.00
	11937	2.53	68.18	24.76	2.75
	11938	2.86	70.82	24.34	2.91
WP - 43.8 KN/m Cal. WP - 37.1 KN/m Cal. WP - 10.5 KN/m Cal. WP - 28.7 KN/m Cal. WP - 19.8 KN/m Cal.	11939	2.60	68.29	25.42	2.69
	11940	2.34	69.08	25.11	2.75
	11941	3.11	72.21	25.26	2.86

Table E2 cont. Average Physical Property Data.

[illegible]

Table E2 cont. Average Physical Property Data.

Test Method	Sample ID (#)	T524 (Directional)										T480		T441	
		Conditioned and Exposed to Light 96 Hours										95% Gloss		FS Cobb Sizing (g/m ²)	
		Color Brightness	95% C.I.	L* Lightness	95% C.I.	a* +Redness -Greenness	95% C.I.	b* +Yellowness -Blueness	95% C.I.						
Case 5 Wet Press No Calendar	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
	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
	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 Wet Press 35 KN/m Calendar	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
	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
	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 2 246 °C No Calendar	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
	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
	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 6 246 °C 35 KN/m Calendar	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
	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
	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
	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
	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
Case 4 260 °C No Calendar	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
	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
	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
Case 1 Commercial Liner - Control Commercial Medium	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
	107811											208.8	5.1	211.6	4.9
	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

Test Method		T524 (Directional)										T480		T441			
	Sample ID (#)	Conditioned and Exposed to Light 96 Hours										Gloss	95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.
		Color Brightness	95% C.I.	L*	95% C.I.	a* +Greenness	95% C.I.	b* +Yellowness	95% C.I.	95% C.I.							

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

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 Wet Press No Calendar	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
	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
	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 Wet Press 35 KN/m Calendar	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
	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
	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 2 246 °C No Calendar	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
	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
	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 6 246 °C 35 KN/m Calendar	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
	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
	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
	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
	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
Case 4 260 °C No Calendar	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
	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
	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
Case 1 Commercial Liner - Control Commercial Medium	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
	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
	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	Sample ID (#)	T494										T494			
		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.	CD	MD
Case 5 Wet Press No Calender	11942	23.75	0.41	59.63	1.13	27.30	0.50	68.08	1.27	20081	388	53069	1361		
	11943	23.53	0.52	57.11	1.20	27.80	0.56	67.31	1.47	19107	405	51404	869		
	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		
		23.74	0.42	58.77	1.17	27.26	0.48	67.89	1.25	19632	430	55338	2971		
Case 3 Wet Press 35 KN/m Calender	11947	23.32	0.39	57.71	1.16	27.31	0.46	67.52	1.25	19223	461	52869	828		
	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		
		26.79	0.71	67.66	1.20	31.24	0.75	79.10	1.51	21592	463	56515	989		
		27.31	0.67	67.47	1.23	31.40	0.74	77.44	1.50	21419	404	53338	2994		
Case 2 246 °C 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		
		26.96	0.59	67.21	1.13	31.72	0.72	78.62	1.26	20997	394	55511	964		
		27.20	0.51	67.10	1.37	31.53	0.62	77.78	1.50	20963	443	56186	942		
	Average	27.08	0.39	67.16	0.89	31.62	0.47	78.20	0.98	20980	296	55849	674		
Case 4 260 °C No Calender	11933	26.23	0.64	66.54	1.16	31.10	0.75	79.42	1.32	20731	475	56241	773		
	11934	27.02	0.80	68.68	1.05	31.31	0.82	79.62	1.16	19886	740	54698	1030		
	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		
		26.99	0.55	75.61	2.22	32.72	0.71	91.33	2.28	18888	340	59413	1432		
Case 1 Commercial Liner - Control	225121	26.00	0.71	75.96	1.53	30.85	0.92	88.90	2.09	18140	753	53794	1052		
	Average	26.50	0.45	75.78	1.35	31.78	0.58	90.11	1.55	18514	413	56604	888		
		12.44	0.20	37.07	0.66	18.88	0.25	55.76	0.88	10569	159	36430	534		
		12.83	0.15	35.92	0.71	19.53	0.20	54.77	0.99	10358	189	35496	504		
		12.03	0.20	34.77	1.01	18.48	0.30	53.26	1.32	9720	191	33436	727		
		12.42	0.19	37.75	0.81	18.79	0.28	56.99	0.85	10163	164	36608	865		
Commercial Medium	107814	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		CD		MD		IPST		IPST		T809	
	Sample ID (#)	Young's Modulus (MN/m ²)	95% C.I.	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. (N)
Case 5 Wet Press No Calender	11942	138.4	2.7	365.9	9.4	152.0	0.4	0.624	0.007		
	11943	131.7	2.8	354.4	6.0	148.1	0.4	0.622	0.007		
	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 Wet Press 35 KN/m Calender	11946	135.3	3.0	381.5	20.5	151.3	0.3	0.634	0.005		
	11947	132.5	3.2	364.5	5.7	150.0	0.3	0.634	0.005		
	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 2 246 °C No Calender	11926	148.9	3.2	389.6	6.8	150.0	0.3	0.693	0.010		
	11930	147.7	2.8	367.7	20.6	152.5	0.4	0.698	0.011		
	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 6 246 °C 35 KN/m Calender	11927	144.8	2.7	382.7	6.6	149.4	0.3	0.728	0.006		
	11928	144.5	3.1	387.4	6.5	150.9	0.3	0.715	0.007		
	Average	144.6	2.0	385.0	4.6	150.1	0.2	0.721	0.005		
	11933	142.9	3.3	387.7	5.3	147.3	0.4	0.685	0.012		
	11934	137.1	5.1	377.1	7.1	150.6	0.4	0.672	0.011		
Case 4 260 °C 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		
	225111	130.2	2.3	409.6	9.9	146.4	0.6	0.701	0.008		
	225121	125.1	5.2	370.9	7.3	147.1	9.4	0.698	0.046		
Case 1 Commercial Liner - Control Commercial Medium	Average	127.6	2.8	390.2	6.1	146.8	4.7	0.700	0.023		
	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
	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 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. (mills)	Soft Caliper (microns)	95% C.I. (mills)	Gurley Porosity (s/100ml)	95% C.I.	FS Bendsen Roughness (ml/min)	95% C.I.	WS Bendsen 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	WS			T538						
Sample ID (#)	ZD-Long. SEM (MN m/kg)	95% C.I.	Soft Caliper (microns)	95% C.I.	Soft Caliper (mills)	Gurley Porosity (s/100ml)	FS 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	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 Bendsen Roughness (ml/min)	95% C.I.	WS Bendsen 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	
	ZD-Long. SEM (MN m/kg)	95% C.I.	Soft Caliper (microns)	95% C.I. (mills)	Soft Caliper (s/100ml)	95% C.I.	Bendtsen Roughness (ml/min)	95% C.I.	FS Sheffield Roughness (SU)	95% C.I.
11951 Front Center Back	0.1236 0.1163 0.1205	0.0032 0.0039 0.0037	219.07 225.50 217.27	3.92 4.58 3.58	8.62 8.88 8.55	0.15 0.18 0.14	1916 1886 1838	130 119 108	2194 2437 2328	94 106 95
11952 Front Center Back	0.1300 0.1220 0.1245	0.0032 0.0031 0.0037	212.28 216.40 217.10	3.84 3.51 4.88	8.36 8.52 8.55	0.15 0.14 0.19	1868 1734 1817	96 80 95	2367 2347 2436	107 81 83
11953 Front Center Back	0.1307 0.1206 0.1246	0.0033 0.0031 0.0033	215.20 220.30 218.88	4.47 4.07 5.36	8.47 8.67 8.62	0.18 0.16 0.21	1808 1746 1693	116 106 94	2358 2405 2238	98 94 89
11954 Front Center Back	0.1327 0.1235 0.1311	0.0031 0.0035 0.0036	219.18 221.15 223.33	4.73 3.86 4.29	8.64 8.71 8.79	0.19 0.15 0.17	1853 1758 1944	113 93 111	2303 2385 2280	73 103 85
11955 Front Center Back	0.1233 0.1065 0.1188	0.0041 0.0026 0.0047	226.07 238.30 235.00	5.81 6.40 6.02	8.90 9.38 9.25	0.23 0.25 0.24	1961 1859 1916	150 130 113	2284 2426 2269	92 135 93
11956 Front Center Back	0.1287 0.1140 0.1235	0.0054 0.0029 0.0046	220.10 229.43 228.17	5.03 7.15 5.79	8.67 9.03 8.98	0.20 0.28 0.23	1872 1876 1982	146 129 144	2267 2282 2214	92 108 103

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

Table E3 cont. Average Physical Property Data by Lane.

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

0.0109 0.0130 0.0104 0.0171 0.0162 0.0128 0.0056 0.0093 0.0149 0.0089 0.0062 0.0072 0.0081 0.0106 0.0120 0.0145 0.0054 0.0187 0.0082 0.0071 0.0027 0.0084 0.0185 0.0139

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	WS						IPST							
	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 Center Back	410	7	3356	34	3432	56	78.1	3.3	0.2216	0.0035	56.5	6.2	0.1855	0.0087
	414	6	3323	89	3465	50	83.7	5.1	0.2289	0.0072	61.4	10.2	0.1916	0.0136
	413	6	3398	50	3457	49	83.7	2.8	0.2273	0.0042	56.4	6.2	0.1849	0.0099
11936 Front Center Back	411	6	3340	66	3440	52	82.4	4.2	0.2266	0.0070	47.8	7.6	0.1712	0.0140
	409	4	3306	76	3423	34	80.0	7.9	0.2237	0.0108	54.4	5.1	0.1828	0.0109
	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 Center Back	412	5	3498	38	3448	38	179.2	7.4	0.3381	0.0066	133.6	16.8	0.2903	0.0150
	413	5	3448	47	3457	40	186.2	11.9	0.3404	0.0090	137.7	12.7	0.2954	0.0176
	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.

Sample ID (#)	Test Methods	WS				IPST				MD			
		Sheffield Roughness (SU)	95% C.I.	Sheffield Roughness (ml/min)	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 Dev.	95% C.I.
11943	Front	415	6	3482	42	3473	51			178.2	8.9	0.3349	0.0073
	Center	409	7	3448	47	3423	59			191.2	12.1	0.3475	0.0123
	Back	411	4	3482	42	3440	34			181.1	5.1	0.3347	0.0034
11944	Front	414	7	3448	38	3465	58			187.3	13.2	0.3412	0.0084
	Center	412	6	3482	58	3448	47			182.5	6.6	0.3409	0.0098
	Back	415	7	3473	32	3473	58			186.9	12.6	0.3421	0.0128
11945	Front	412	6	3482	42	3448	47			188.5	10.4	0.3449	0.0095
	Center	412	5	3473	42	3448	38			184.5	9.6	0.3399	0.0081
	Back	417	7	3482	42	3490	57			175.7	19.3	0.3302	0.0156
11946	Front	386	4	3164	47	3231	31			116.3	9.9	0.2692	0.0127
	Center	371	2	3156	24	3103	20			104.9	8.5	0.2552	0.0122
	Back	349	8	2930	80	2922	66			101.7	11.6	0.2503	0.0124
11947	Front	397	7	3365	38	3323	57			147.9	7.6	0.3056	0.0075
	Center	391	6	3306	32	3273	52			142.3	8.8	0.2957	0.0104
	Back	389	6	3356	44	3256	52			135.0	8.7	0.2899	0.0100
11948	Front	384	11	3172	52	3214	90			124.0	11.1	0.2762	0.0124
	Center	382	2	3244	29	3199	20			120.7	8.4	0.2744	0.0095
	Back	387	6	3156	40	3239	49			122.3	8.5	0.2758	0.0095
11949	Front	381	7	3147	50	3189	59			125.6	5.8	0.2803	0.0078
	Center	385	2	3253	27	3225	21			121.2	11.2	0.2755	0.0112
	Back	383	6	3223	32	3206	49			113.4	8.5	0.2647	0.0122
11950	Front	413	5	3315	64	3457	40			88.4	6.6	0.2355	0.0077
	Center	419	7	3323	57	3507	59			87.7	5.5	0.2348	0.0053
	Back	415	8	3315	58	3473	70			89.3	4.7	0.2360	0.0089
										64.4	4.4	0.1987	0.0068
										60.6	8.0	0.1932	0.0111
										61.7	7.8	0.1939	0.0140

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	WS			FS			WS			IPST			MD		
	Sample ID (#)	Sheffield Roughness (SU)	95% C.I.	Sheffield Roughness (ml/min)	95% C.I.	Sheffield Roughness (ml/min)	95% C.I.	Sheffield Roughness (ml/min)	95% C.I.	CD	FS Emveco Micro Dev.	95% C.I.	FS Emveco Micro Dev.	95% C.I.	MD
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	WS				FS				WS				IPST			
	Sheffield Roughness (SU)	95% C.I.	Sheffield Roughness (ml/min)	95% C.I.	95% C.I.	Sheffield Roughness (ml/min)	95% C.I.	95% C.I.	Sheffield Roughness (ml/min)	95% C.I.	95% C.I.	95% C.I.	CD FS Emveco Micro Dev.	CD FS Emveco Micro Dev.	CD FS Emveco Micro Dev.	MD FS Emveco Micro Ave. 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	TS27 (Diffuse)				TS27 (Diffuse)					
	As Made				Conditioned and Exposed to Light 96 Hours					
Sample ID (#)	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greenness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greenness	b* +Yellowness -Blueness
11926 Front Center Back	13.96	0.06	56.95	6.42	24.07	13.06	0.13	55.09	7.36	22.83
	14.30	0.06	57.35	6.34	23.92	13.27	0.03	55.45	7.28	22.92
	14.06	0.14	57.04	6.33	23.98	13.01	0.06	55.15	7.21	23.08
11927 Front Center Back	13.95	0.09	56.91	6.39	24.01	13.15	0.13	55.33	7.16	23.00
	14.19	0.08	57.20	6.35	23.92	13.29	0.05	55.49	7.09	23.06
	13.95	0.12	56.90	6.38	23.97	13.00	0.13	55.14	7.15	23.13
11928 Front Center Back	14.04	0.11	57.02	6.45	24.00	13.19	0.29	55.38	7.23	22.91
	14.20	0.05	57.28	6.29	23.94	13.30	0.05	55.54	7.13	23.02
	14.04	0.05	56.98	6.38	23.90	13.06	0.11	55.17	7.27	22.96
11930 Front Center Back	14.09	0.13	57.05	6.41	23.84	13.21	0.21	55.23	7.17	22.74
	14.28	0.11	57.29	6.39	23.89	13.18	0.05	55.23	7.16	22.81
	13.96	0.13	56.86	6.39	23.86	13.05	0.18	55.02	7.22	22.80
11931 Front Center Back	14.20	0.11	57.23	6.34	23.92	13.38	0.10	55.51	7.12	22.76
	14.30	0.10	57.33	6.33	23.99	13.43	0.19	55.60	7.17	22.73
	13.98	0.08	56.92	6.34	23.97	13.27	0.08	55.29	7.30	22.63
11932 Front Center Back	14.09	0.07	57.07	6.44	23.97	13.42	0.10	55.49	7.25	22.59
	14.15	0.04	57.16	6.33	23.95	13.38	0.05	55.47	7.10	22.68
	13.94	0.10	56.88	6.35	23.93	13.35	0.12	55.42	7.21	22.73
11933 Front Center Back	14.13	0.16	57.07	6.31	23.81	13.45	0.11	55.44	7.13	22.52
	14.36	0.13	57.36	6.39	23.73	13.57	0.07	55.65	7.19	22.45
	14.14	0.07	56.99	6.44	23.74	13.44	0.12	55.53	6.99	22.59
11934 Front Center Back	14.12	0.14	57.07	6.36	23.85	13.27	0.12	55.29	7.12	22.69
	14.47	0.08	57.48	6.22	23.70	13.48	0.06	55.61	7.09	22.64
	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 -Greenness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greenness	b* +Yellowness -Blueness
11935 Front Center Back	14.17	0.10	57.06	6.31	23.74	13.42	0.16	55.44	7.31	22.56
	14.37	0.08	57.33	6.37	23.68	13.73	0.12	55.86	7.08	22.40
	14.21	0.02	57.06	6.47	23.62	13.58	0.18	55.72	7.07	22.49
11936 Front Center Back	14.13	0.19	56.96	6.47	23.64	13.56	0.14	55.73	7.49	21.43
	14.32	0.09	57.24	6.31	23.63	13.79	0.08	56.03	7.43	21.41
	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 Center Back	15.49 15.67 15.61	0.21 0.13 0.10	59.28 59.41 59.36	5.35 5.77 5.76	24.17 24.10 24.15	14.82 14.99 14.94	0.04 0.08 0.17	57.72 57.89 57.88	7.11 7.06 7.03	21.79 21.74 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	95%	L*	a*	b*	Brightness		Color	95%	L*	a*	b*	Brightness	
			Lightness	+Redness	+Yellowness	-Greenness	-Blueness			Lightness	+Redness	+Yellowness	-Greenness	-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 -Greenness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greenness	b* +Yellowness -Blueness
11951 Front Center Back	13.43	0.10	56.09	6.55	24.05	12.99	0.14	55.01	7.64	21.64
	13.71	0.11	56.48	6.44	23.95	13.09	0.06	55.08	7.49	21.57
	13.56	0.15	56.18	6.63	23.94	12.90	0.14	54.83	7.59	21.62
11952 Front Center Back	13.56	0.13	56.20	6.49	23.98	13.04	0.10	55.07	7.51	21.64
	13.72	0.08	56.39	6.50	23.76	13.10	0.07	55.06	7.54	21.51
	13.44	0.13	56.00	6.65	23.87	12.86	0.11	54.79	7.57	21.64
11953 Front Center Back	13.46	0.09	56.00	6.57	23.81	12.82	0.12	54.61	7.48	21.35
	13.64	0.06	56.23	6.45	23.73	13.05	0.07	54.88	7.49	21.24
	13.41	0.09	55.83	6.61	23.73	12.83	0.15	54.56	7.56	21.30
11954 Front Center Back	13.69	0.09	56.34	6.45	23.83	13.16	0.21	55.04	7.37	21.24
	14.13	0.04	56.83	6.34	23.58	13.47	0.05	55.50	7.16	21.30
	13.62	0.13	56.19	6.27	23.74	13.21	0.19	55.06	7.40	21.19
11955 Front Center Back	13.89	0.15	56.54	6.32	23.73	13.32	0.19	55.28	7.24	21.27
	14.25	0.06	57.06	6.13	23.64	13.50	0.12	55.50	7.23	21.27
	13.84	0.08	56.47	6.23	23.68	13.36	0.14	55.26	7.30	21.19
11956 Front Center Back	13.98	0.12	56.64	6.09	23.58	13.36	0.19	55.27	7.26	21.14
	14.26	0.12	56.99	6.11	23.55	13.48	0.06	55.43	7.16	21.18
	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)				
Sample ID (#)	As Made					Conditioned and Exposed to Light 96 Hours				
	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greenness	b* +Yellowness -Blueness	Color Brightness	95% C.I.	L* Lightness	a* +Redness -Greenness	b* +Yellowness -Blueness
Commercial Medium										
107811 Center Edge										
107812 Center Edge										
107813 Center Edge										
107814 Center Edge										
107816 Center Edge										
Commercial Liner										
225111 Center Edge	16.03 16.01	0.07 0.06	58.63 58.62	6.47 6.49	21.96 21.97	15.97 15.91	0.05 0.04	58.83 58.75	6.56 6.51	21.14 21.13
225121 Center Edge	16.16 16.12	0.09 0.07	58.86 58.80	6.31 6.41	22.11 22.08	15.92 15.88	0.06 0.07	58.71 58.72	6.54 6.53	20.95 21.04

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T524 (Directional)					T480		T441		T403				
Sample ID (#)	Conditioned and Exposed to Light 96 Hours					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.
	Color Brightness	95% C.I.	L* Lightness	+Redness -Greeness	a* +Yellowness -Blueness									
11926 Front Center Back	13.32	0.22	55.74	7.46	22.15	13.00	0.21	294.42	289.50	6.10	78.04	5.06	538.1	34.9
	13.59	0.26	56.17	7.32	22.14	12.52	0.35	304.54	293.92	12.36	76.84	3.34	529.8	23.0
	13.51	0.30	55.99	7.43	22.14	12.61	0.30	315.11	308.16	19.96	80.92	4.93	557.9	34.0
11927 Front Center Back	13.48	0.34	56.00	7.42	22.22	13.09	0.40	293.53	292.28	10.70	79.00	5.46	544.7	37.6
	13.73	0.32	56.23	7.30	22.07	13.09	0.63	295.69	297.37	15.80	75.24	5.56	518.8	38.3
	13.44	0.42	55.92	7.37	22.21	13.26	0.57	292.20	295.33	4.78	75.92	5.19	523.4	35.8
11928 Front Center Back	13.28	0.32	55.72	7.38	22.22	12.75	0.30	290.95	283.72	16.99	77.63	3.51	535.3	24.2
	13.60	0.21	56.18	7.28	22.26	12.96	0.38	295.82	300.51	5.93	76.14	7.17	525.0	49.4
	13.36	0.31	55.78	7.38	22.16	13.09	0.33	288.47	297.59	13.22	80.02	4.18	551.7	28.8
11930 Front Center Back	13.40	0.26	55.75	7.37	22.00	12.04	0.32	296.85	297.17	9.71	78.19	3.65	539.1	25.2
	13.55	0.37	55.94	7.39	21.91	12.04	0.32	313.61	306.98	11.91	75.78	4.98	522.5	34.3
	13.46	0.33	55.77	7.23	21.91	11.98	0.35	294.27	301.32	14.32	79.70	3.21	549.6	22.1
11931 Front Center Back	13.28	0.23	55.60	7.33	22.02	11.85	0.32	277.85	295.57	12.56	80.29	3.38	553.6	23.3
	13.46	0.39	55.91	7.37	22.08	12.16	0.28	291.66	299.68	19.98	76.04	5.52	524.3	38.1
	13.33	0.27	55.67	7.41	22.05	12.08	0.34	286.82	275.96	8.62	79.48	5.56	548.0	38.3
11932 Front Center Back	13.47	0.29	55.84	7.26	21.94	12.20	0.33	277.48	271.92	11.88	78.64	4.17	542.2	28.7
	13.76	0.19	56.20	7.31	21.86	12.13	0.36	286.67	311.50	8.35	74.72	2.49	515.2	17.2
	13.61	0.32	56.03	7.22	21.93	12.07	0.23	300.98	313.66	11.10	79.05	4.00	545.0	27.6
11933 Front Center Back	13.71	0.48	56.06	7.25	21.73	13.83	0.39	301.67	294.59	22.14	70.98	4.44	489.4	30.6
	13.75	0.18	56.18	7.15	21.85	13.67	0.35	300.93	296.33	5.91	74.72	5.95	515.2	41.0
	13.59	0.33	55.91	7.28	21.82	13.40	0.51	298.23	293.33	10.40	75.02	3.44	517.2	23.7
11934 Front Center Back	13.54	0.37	55.95	7.27	21.88	14.13	0.30	308.40	294.39	21.11	74.90	5.10	516.4	35.1
	13.90	0.16	56.33	7.21	21.75	12.77	0.92	311.40	316.86	10.91	75.22	4.37	518.6	30.1
	13.67	0.46	56.09	7.25	21.90	13.25	0.41	304.79	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						
Sample ID (#)	Conditioned and Exposed to Light 96 Hours						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.	
	Color Brightness	95% C.I.	L* Lightness	+Redness -Greenness	a* +Redness -Greenness	b* +Yellowness -Blueness										
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	15.31	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					
Sample ID (#)	Conditioned and Exposed to Light 96 Hours										95% C.I.	FS Cobb Sizing (g/m^2)	95% C.I.	WS Cobb Sizing (g/m^2)	95% C.I.	95% C.I.	Burst (psi)	Burst (kPa)	95% C.I.
	Color Brightness	95% C.I.	L* Lightness	+Redness -Greeness	a* +Yellowness -Blueness	Gloss													
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.

Sample ID (#)	Test Methods		IPST				T826				T822			
	MD Crack Angle (deg)	95% C.I.	CD Crack Angle (deg)	95% C.I.	CD STFI (lb/in)	95% C.I.	MD STFI (lb/in)	95% C.I.	CD STFI Index (N*/m/g)	95% C.I.	Geo Mean STFI Index (N*/m/g)	95% C.I.	CD Ring Crush (lb/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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	24.89	0.55	10.13	0.43
11933														
Front	54.9	5.7	65.0	6.2	17.50	0.74	28.93	0.74	20.52	0.91	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	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	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	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	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	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 (lb/in)	95% C.I.	MD STFI (lb/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 (lb/in)	95% C.I.
11935	Front Center Back	71.2 71.9 70.9	4.7 5.5 4.1	74.0 68.1 69.2	7.0 7.2 6.2	17.13 16.05 16.76	0.42 0.35 0.65	30.47 29.99 28.38	0.85 0.74 1.00	19.79 18.61 19.47	0.48 0.42 0.76	35.41 34.41 32.80	0.96 0.88 1.18	26.47 25.30 25.27	0.51 0.45 0.73	10.45 10.40 10.75	0.43 0.23 0.23
11936	Front Center Back	71.2 66.0 72.2	5.6 5.8 5.4	73.2 66.1 68.0	10.8 6.5 8.2	17.60 15.98 17.03	0.80 0.58 0.77	30.65 30.14 29.71	0.99 0.59 1.06	20.66 18.60 19.79	0.96 0.67 0.87	35.22 34.90 34.42	1.16 0.66 1.17	26.98 25.48 26.10	0.81 0.59 0.80	10.40 9.83 10.49	0.35 0.29 0.36
11937	Front Center Back																
11938	Front Center Back																
11939	Front Center Back																
11940	Front Center Back																
11941	Front Center Back																
11942	Front Center Back	58.4 65.3 69.6	6.7 6.3 9.4	78.3 84.9 68.7	8.8 9.8 9.4	15.51 14.24 15.26	0.54 0.52 0.87	27.09 27.04 27.12	1.25 0.72 1.12	18.05 16.50 17.84	0.62 0.60 1.04	30.33 31.25 31.65	1.39 0.80 1.31	23.40 22.71 23.76	0.74 0.57 0.92	9.55 8.93 9.34	0.52 0.24 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 (lb/in)	95% C.I.	MD STFI (lb/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 (lb/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 (lb/in)	95% C.I.	MD STFI (lb/in)	95% C.I.	CD STFI Index (N*/m/g)	95% C.I.	Geo Mean STFI Index (N*/m/g)	95% C.I.	CD Ring Crush (lb/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	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	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	9.58	0.31
11952	Front					16.07	0.42	28.20	0.56	19.04	0.49	33.65	0.66	9.64	0.19
	Center					15.03	0.51	27.79	0.58	18.07	0.61	33.17	0.76	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	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	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	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	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	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	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	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	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	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	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	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	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	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 (lb/in)	95% C.I.	MD STFI (lb/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 (lb/in)	95% C.I.
Commercial Medium																
107811					11.69	0.43	21.35	0.60	17.33	0.60	32.14	0.85	23.60	0.57	5.17	0.19
Center					10.75	0.25	21.29	0.79	16.18	0.38	31.31	1.07	22.50	0.51	5.37	0.15
Edge																
107812					10.77	0.61	20.19	0.64	16.33	0.90	30.74	0.98	22.39	0.76	5.13	0.33
Center					11.03	0.23	19.93	0.34	16.93	0.32	30.85	0.42	22.85	0.29	5.05	0.21
Edge																
107813					10.35	0.44	20.00	0.51	16.02	0.66	31.10	0.79	22.32	0.56	4.53	0.28
Center					10.91	0.22	20.70	0.40	16.65	0.33	31.60	0.62	22.94	0.36	4.83	0.21
Edge																
107814					11.14	0.29	21.99	0.49	16.86	0.44	31.66	0.69	23.10	0.41	5.35	0.28
Center					10.97	0.23	20.24	0.57	16.39	0.34	30.35	0.73	22.29	0.32	5.12	0.16
Edge																
107816					10.57	0.26	20.58	0.53	16.56	0.37	31.29	0.83	22.76	0.42	4.86	0.35
Center					11.09	0.21	21.47	0.46	16.64	0.29	32.28	0.63	23.17	0.30	4.97	0.15
Edge																
Commercial Liner																
225111					17.83	0.69	31.04	0.72	21.33	0.82	37.06	0.90	28.12	0.70	10.51	0.45
Center	67.1	4.2	85.4	8.9	17.91	0.48	33.80	0.77	21.71	0.56	40.30	0.88	29.58	0.54	9.90	0.41
Edge	71.8	3.6	83.7	3.4												
225121					17.97	0.81	32.27	1.18	21.23	0.98	38.31	1.36	28.51	0.90	10.57	0.45
Center	77.8	3.6	89.5	7.2	18.20	0.50	33.65	0.63	21.75	0.62	40.48	0.73	29.67	0.56	10.42	0.42
Edge	70.3	3.6	81.2	5.5												

Table E3 cont. Average Physical Property Data by Lane.

Test Methods		T494													
Sample ID (#)	MD Ring Crush (lb/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			MD					
							Tensile (lb/in)	95% C.I.	Tensile (lb/in)	95% C.I.	Tensile (lb/in)	95% C.I.	Tensile (lb/in)	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 (lb/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 (lb/in)	95% C.I.	MD Tensile (lb/in)	95% C.I.	CD Tensile (N*m/g)	95% C.I.	MD Tensile Index (N*m/g)
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
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
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
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
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
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
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
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
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

Table E3 cont. Average Physical Property Data by Lane.

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

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T494			IPST			IPST			T809			
	CD	MD		CD	MD		OD Basis	95% C.I.	OD Density	95% C.I.	Concora (lbf)	95% C.I.	Concora (N)
Sample ID (#)	Young's Modulus (lbf/in ²)	95% C.I.	Young's Modulus (lbf/in ²)	95% C.I.	Young's Modulus (MN/m ²)	95% C.I.	Weight (g/m ²)	95% C.I.	(g/cm ³)				
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	
	CD	MD	CD	MD	OD Basis	95% C.I.	OD Density	95% C.I.	Concora (lbf)	95% C.I. (N)
Sample ID (#)	Young's Modulus (lbf/in ²)	Young's Modulus (lbf/in ²)	Young's Modulus (MN/m ²)	Young's Modulus (MN/m ²)	Weight (g/m ²)		(g/cm ³)			
11935										
Front	21469	413	51977	148.0	151.43	0.69	0.720	0.016		
Center	19901	313	53006	1075	152.13	0.48	0.688	0.015		
Back	20772	321	50376	1253	152.37	0.65	0.678	0.015		
11936										
Front	21453	392	51957	1440	150.20	0.67	0.710	0.023		
Center	19720	347	53156	889	149.29	0.48	0.700	0.011		
Back	20729	434	52115	838	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	151.56	0.55	0.617	0.011		
Back	20645	361	51827	1844	151.15	0.82	0.621	0.012		

Table E3 cont. Average Physical Property Data by Lane.

Sample ID (#)	T494			IPST			IPST			T809		
	CD	MD	Young's Modulus (lb/in ²)	CD	MD	Young's Modulus (MN/m ²)	OD Basis Weight (g/m ²)	95% C.I.	OD Density (g/cm ³)	95% C.I.	Concora (lb)	95% C.I. (N)
11943												
Front	19489	810	51714	1126	134.4	5.6	148.64	0.68	0.619	0.015		
Center	18255	473	51820	2128	125.9	3.3	147.37	0.46	0.615	0.009		
Back	19577	661	50677	1635	135.0	4.6	148.62	0.76	0.636	0.016		
11944												
Front	20370	685	52108	2331	140.4	4.7	155.41	0.63	0.643	0.013		
Center	19917	629	53367	1579	137.3	4.3	153.87	0.53	0.613	0.012		
Back	20667	450	52348	1751	142.5	3.1	155.10	0.92	0.630	0.016		
11945												
Front	20960	398	53326	1116	144.5	2.7	154.49	0.73	0.633	0.017		
Center	19841	307	54710	1255	136.8	2.1	153.61	0.62	0.603	0.008		
Back	20506	394	52137	1020	141.4	2.7	153.53	0.70	0.613	0.013		
11946												
Front	20734	729	57862	9785	142.9	5.0	152.19	0.67	0.622	0.012		
Center	18855	469	54823	859	130.0	3.2	149.56	0.41	0.630	0.006		
Back	19306	587	53329	1350	133.1	4.0	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	150.36	0.51	0.626	0.006		
Back	19730	522	51601	950	136.0	3.6	149.17	0.69	0.645	0.009		
11948												
Front	19702	285	51015	1373	135.8	2.0	150.16	0.74	0.630	0.009		
Center	18389	261	51179	1038	126.8	1.8	149.54	0.49	0.632	0.006		
Back	19596	292	51203	1066	135.1	2.0	150.68	0.80	0.630	0.018		
11949												
Front	19328	460	49424	1288	133.3	3.2	152.46	0.78	0.637	0.013		
Center	17894	276	50068	778	123.4	1.9	150.00	0.46	0.628	0.010		
Back	18800	302	49999	1085	129.6	2.1	151.50	0.68	0.634	0.014		
11950												
Front	20977	391	52208	1776	144.6	2.7	149.15	0.54	0.663	0.012		
Center	20443	492	54043	2225	140.9	3.4	150.42	0.53	0.638	0.013		
Back	20558	330	48494	1126	141.7	2.3	149.30	0.64	0.650	0.013		

Table E3 cont. Average Physical Property Data by Lane.

Test Methods	T494				IPST		IPST		T809	
	CD	MD		CD	MD		OD Basis	95% C.I.	OD	95% C.I.
Sample ID (#)	Young's Modulus (lb/in ²)	95% C.I.	Young's Modulus (lb/in ²)	95% C.I.	Young's Modulus (MN/m ²)	95% C.I.	Weight (g/m ²)		Density (g/cm ³)	
11951										
Front	19973	791	53967	1591	137.7	5.5	149.72	0.53	0.684	0.014
Center	17928	659	55373	1592	123.6	4.5	149.42	0.46	0.663	0.016
Back	20035	543	48910	1917	138.1	3.7	149.43	0.52	0.688	0.012
11952										
Front	21083	288	53880	1766	145.4	2.0	147.29	0.46	0.694	0.014
Center	20089	400	54969	1923	138.5	2.8	147.15	0.41	0.680	0.012
Back	20244	307	51689	1794	139.6	2.1	146.82	0.39	0.677	0.015
11953										
Front	20758	497	52874	1333	143.1	3.4	149.30	0.52	0.695	0.013
Center	19454	323	52970	1078	134.1	2.2	149.55	0.53	0.679	0.014
Back	20032	247	51845	1455	138.1	1.7	148.39	0.61	0.679	0.015
11954										
Front	21820	371	51894	8283	150.4	2.6	151.64	0.49	0.692	0.016
Center	19867	374	54368	1356	137.0	2.6	151.76	0.40	0.687	0.013
Back	20317	367	50945	1558	140.1	2.5	151.44	0.53	0.679	0.014
11955										
Front	20698	654	53975	1648	142.7	4.5	151.69	0.59	0.672	0.017
Center	19461	493	54644	1307	134.2	3.4	152.38	0.54	0.640	0.017
Back	20355	532	52396	1455	140.3	3.7	152.69	0.65	0.651	0.015
11956										
Front	19903	930	53212	1341	137.2	6.4	151.80	0.57	0.690	0.017
Center	19102	455	54504	1089	131.7	3.1	150.38	0.57	0.658	0.016
Back	19910	267	51943	669	137.3	1.8	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	MD		CD		MD		OD Basis Weight (g/m^2)	95% C.I.	OD Density (g/cm^3)	95% C.I.	Concora (lbf)	95% C.I. (N)	95% C.I.	
		Young's Modulus (lb/in^2)	95% C.I.	Young's Modulus (lb/in^2)	95% C.I.	Young's Modulus (MN/m^2)	95% C.I.								Young's Modulus (MN/m^2)
Commercial Medium 107811 Center Edge	10887	226	36889	1075	75.1	1.6	254.3	7.4	115.64	0.61	0.616	49.05	2.71	218.17	12.06
	10411	182	36201	642	71.8	1.3	249.6	4.4	116.97	0.47	0.616	50.23	1.10	223.40	4.89
107812 Center Edge	9949	285	35298	1124	68.6	2.0	243.4	7.8	115.07	5.56	0.636	49.25	1.86	219.06	8.29
	10563	199	35596	589	72.8	1.4	245.4	4.1	115.02	0.46	0.629	48.45	1.13	215.51	5.03
107813 Center Edge	9704	359	33890	1864	66.9	2.5	233.6	12.9	112.91	0.69	0.626	47.85	3.01	212.84	13.40
	9728	247	33210	726	67.1	1.7	229.0	5.0	114.67	0.43	0.637	50.18	1.32	223.18	5.87
107814 Center Edge	10328	238	37180	1692	71.2	1.6	256.3	11.7	116.77	0.86	0.618	51.15	1.93	227.52	8.59
	10081	219	36322	1075	69.5	1.5	250.4	7.4	116.15	0.53	0.611	46.88	1.62	208.50	7.19
107816 Center Edge	10525	253	35841	2795	72.6	1.7	247.1	19.3	114.30	0.79	0.624	49.05	2.08	218.17	9.23
	10186	499	36688	660	70.2	3.4	252.9	4.6	115.09	0.44	0.618	52.18	1.76	232.07	7.82
Commercial Liner 225111 Center Edge	18752	749	58356	1699	129.3	5.2	402.3	11.7	146.24	1.11	0.699				
	18957	401	59941	2034	130.7	2.8	413.3	14.0	146.46	0.79	0.702				
225121 Center Edge	16664	1033	54236	2255	114.9	7.1	373.9	15.5	149.67	1.05	0.699				
	18878	876	53573	1261	130.1	6.0	369.4	8.7	145.88	14.07	0.697				

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 (#)	225121	Outer Liner ID (#)	225111	Center ECT (lb/in)	95% C.I.	Center ECT (kN/m)	95% C.I.	Edge ECT (lb/in)	95% C.I.	Edge ECT (kN/m)	95% C.I.		
Case 1		Commercial	Commercial														
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		Center ECT (lb/in)	95% C.I.	Center ECT (kN/m)	95% C.I.	Edge ECT (lb/in)	95% C.I.	Edge ECT (kN/m)	95% C.I.
				ID (#)	Outer Liner ID (#)								
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		Single Face		95%		Single Face		95%		C.I.	
	Center	Glue	Weight	Center	Edge	95%	Center	Flute	Center	Edge	95%	Center	Flute	Center	Edge	Center	Edge	Center	Edge	Center	Edge	Center	Edge	Center	Edge
Case Number (#)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)	Weight (gsm)
Case 5																									
Group 1-10	12.01	5.51	15.68	4.76	3.68	0.16	3.17	0.16	0.02	0.02	0.02	0.02	0.02	0.02	0.02	51.50	1.37	50.66	2.53	51.50	1.37	50.66	2.53	51.50	1.37
Group 11-20	21.93	2.97	20.91	4.20	3.85	0.02	3.34	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	49.72	1.53	50.91	1.33	49.72	1.53	50.91	1.33	49.72	1.53
Group 21-30	16.04	3.19	13.16	5.25	3.73	0.08	3.22	0.08	0.04	0.04	0.04	0.04	0.04	0.04	0.04	47.91	2.10	49.05	2.86	47.91	2.10	49.05	2.86	47.91	2.10
Group 31-40	16.39	4.63	19.09	4.36	3.70	0.10	3.19	0.10	0.07	0.07	0.07	0.07	0.07	0.07	0.07	50.77	1.85	52.56	2.83	50.77	1.85	52.56	2.83	50.77	1.85
Average	16.60	2.14	17.21	2.23	3.74	0.05	3.23	0.05	0.03	0.03	0.03	0.03	0.03	0.02	0.02	49.97	0.86	50.79	1.13	49.97	0.86	50.79	1.13	49.97	0.86
Case 6																									
Group 1-10	21.57	4.60	20.50	4.76	3.65	0.04	3.24	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	47.08	4.26	45.02	2.61	47.08	4.26	45.02	2.61	47.08	4.26
Group 11-20	22.27	4.20	25.19	3.89	3.62	0.05	3.20	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	42.37	2.26	43.19	2.98	42.37	2.26	43.19	2.98	42.37	2.26
Group 21-30	21.65	3.01	25.96	4.84	3.62	0.03	3.20	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	38.86	2.19	35.00	2.89	38.86	2.19	35.00	2.89	38.86	2.19
Group 31-40	25.99	2.84	24.02	2.39	3.58	0.04	3.17	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	38.44	2.42	38.32	1.40	38.44	2.42	38.32	1.40	38.44	2.42
Average	22.87	1.71	23.92	1.88	3.62	0.02	3.20	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	41.69	1.68	40.38	1.69	41.69	1.68	40.38	1.69	41.69	1.68

Table E4 cont. Combined Board Test Data.

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

Table E4 cont. Combined Board Test Data.

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

Test Methods		T825								T836							
Case Number (#)	Center		Edge		Center		Edge		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.	
	Flat	Crush (psi)	95% C.I.	Flat	Crush (psi)	95% C.I.	Flat	Crush (kPa)									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	

Test Methods		T825						T836									
Case	Number (#)	Center		Edge		Center		Edge		MD		CD		MD		CD	
		Flat	95% C.I.	Flat	Crush	95% C.I.	Flat	Crush	95% C.I.	Flat	Crush	Flexural Stiffness (lb-in)	95% C.I.	Flexural Stiffness (lb-in)	95% C.I.	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	
	MD Flex Combined Caliper (mm)		95% C.I. Flute Caliper (mm)		CD Flex Combined Caliper (mm)		95% C.I. Flute Caliper (mm)	
Case 1								
Group 1-10	4.01	0.02	4.00	4.01	0.01	0.01	4.01	4.01
Group 11-20	4.02	0.01	4.01	4.01	0.01	0.01	4.00	4.00
Group 21-30	4.05	0.01	4.04	4.04	0.01	0.01	4.03	4.03
Group 31-40	4.07	0.02	4.07	4.09	0.01	0.01	4.09	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	0.02	3.82	3.82
Group 11-20	3.84	0.01	3.83	3.81	0.02	0.02	3.81	3.81
Group 21-30	3.75	0.02	3.75	3.73	0.02	0.02	3.72	3.72
Group 31-40	3.86	0.01	3.85	3.87	0.01	0.01	3.87	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	0.02	3.65	3.65
Group 11-20	3.71	0.02	3.70	3.64	0.03	0.03	3.63	3.63
Group 21-30	3.67	0.03	3.66	3.62	0.05	0.05	3.61	3.61
Group 31-40	3.82	0.02	3.81	3.83	0.02	0.02	3.82	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	0.04	3.69	3.69
Group 11-20	3.77	0.01	3.76	3.71	0.02	0.02	3.71	3.71
Group 21-30	3.71	0.03	3.71	3.67	0.02	0.02	3.66	3.66
Group 31-40	3.87	0.06	3.86	3.83	0.08	0.08	3.83	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	0.04	3.72	3.72
Group 11-20	3.83	0.01	3.83	3.80	0.03	0.03	3.79	3.79
Group 21-30	3.83	0.03	3.83	3.80	0.03	0.03	3.79	3.79
Group 31-40	3.86	0.05	3.85	3.85	0.04	0.04	3.84	3.84
Average	3.82	0.02		3.79		0.02		

Table E4 cont. Combined Board Test Data.

Test Methods	T411		IPST		T411		IPST	
	MD Flex Combined Caliper (mm)	95% C.I.	MD Flex Flute Caliper (mm)	95% C.I.	CD Flex Combined Caliper (mm)	95% C.I.	CD Flex Flute Caliper (mm)	95% C.I.
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		

Test Methods		Corrugator				T813	
Case Number (#)	Group Order Code	Press Temp (°C)	Calendar Load (KN/m)	Inner		Manufactures	
				Liner ID (#)	Outer Liner ID (#)	Glue Joint (lb/in)	95% C.I. Joint (KN/m)
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			Top-Bottom			Top-Bottom			Top-Bottom		
		Box	95% C.I.	Deflection @ Peak Load (in)	95% C.I.	Box	Peak Load (kN)	95% C.I.	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		Side-Side Deflection @ Peak Load		Side-Side Box		Side-Side Box		Side-Side Box		Side-Side Box	
		Peak Load (lbf)	95% C.I.	(in)	95% C.I.	Peak Load (kN)	95% C.I.	Peak Load (kN)	95% C.I.	Peak Load (mm)	95% C.I.		
Case 1													
Group 1-10		391.50	25.43	0.54	0.09	1.74	0.11	1.74	0.11	13.77	2.16	13.77	2.16
Group 11-20		340.40	28.43	0.65	0.08	1.51	0.13	1.51	0.13	16.43	1.92	16.43	1.92
Group 21-30		360.70	33.94	0.59	0.07	1.60	0.15	1.60	0.15	14.99	1.77	14.99	1.77
Average		364.20	16.85	0.59	0.04	1.62	0.07	1.62	0.07	15.06	1.07	15.06	1.07
Case 2A													
Group 1-10		347.20	45.95	0.54	0.17	1.54	0.20	1.54	0.20	13.72	4.38	13.72	4.38
Group 11-20		391.80	10.04	0.54	0.04	1.74	0.04	1.74	0.04	13.69	1.07	13.69	1.07
Group 21-30		370.20	26.46	0.56	0.05	1.65	0.12	1.65	0.12	14.25	1.27	14.25	1.27
Average		369.73	17.15	0.55	0.05	1.64	0.08	1.64	0.08	13.89	1.37	13.89	1.37
Case 2B													
Group 1-10		334.80	13.42	0.48	0.04	1.49	0.06	1.49	0.06	12.22	1.12	12.22	1.12
Group 11-20		373.50	30.50	0.45	0.08	1.66	0.14	1.66	0.14	11.30	2.01	11.30	2.01
Group 21-30		327.20	28.20	0.44	0.11	1.46	0.13	1.46	0.13	11.13	2.88	11.13	2.88
Average		345.17	14.85	0.45	0.04	1.54	0.07	1.54	0.07	11.55	1.09	11.55	1.09
Case 3													
Group 1-10		354.70	27.95	0.47	0.05	1.58	0.12	1.58	0.12	12.04	1.26	12.04	1.26
Group 11-20		295.20	22.66	0.31	0.13	1.31	0.10	1.31	0.10	7.87	3.25	7.87	3.25
Group 21-30		322.00	24.84	0.39	0.11	1.43	0.11	1.43	0.11	9.96	2.91	9.96	2.91
Average		323.97	15.72	0.39	0.06	1.44	0.07	1.44	0.07	9.96	1.47	9.96	1.47
Case 4													
Group 1-10		432.80	17.08	0.51	0.03	1.93	0.08	1.93	0.08	13.03	0.80	13.03	0.80
Group 11-20		400.40	29.35	0.48	0.07	1.78	0.13	1.78	0.13	12.09	1.87	12.09	1.87
Group 21-30		351.10	26.47	0.51	0.05	1.56	0.12	1.56	0.12	13.03	1.35	13.03	1.35
Average		394.77	17.88	0.50	0.03	1.76	0.08	1.76	0.08	12.72	0.73	12.72	0.73
Case 5													
Group 1-10		431.10	27.22	0.46	0.04	1.92	0.12	1.92	0.12	11.66	0.89	11.66	0.89
Group 11-20		384.10	37.22	0.42	0.08	1.71	0.17	1.71	0.17	10.69	1.92	10.69	1.92
Group 21-30		312.00	15.16	0.36	0.08	1.39	0.07	1.39	0.07	9.02	2.07	9.02	2.07
Average		375.73	23.35	0.41	0.04	1.67	0.10	1.67	0.10	10.46	0.96	10.46	0.96

Table E5 cont. Box Test Data.

Test Methods	T804									
	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.	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		