Institute of Paper Science and Technology

THE USE OF OLD CORRUGATED CONTAINERS AND OLD NEWSPRINT AS A COMPONENT OF THE FURNISH FOR MULTIWALL SACKS

Project 3756

Final Report

CONFIDENTIAL

to

THE KRAFT AND PACKAGING PAPERS DIVISION
OF THE
AMERICAN FOREST AND PAPER ASSOCIATION

August 10, 1994

IPST

Atlanta, Georgia

INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY
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INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

Atlanta, Georgia

THE USE OF OLD CORRUGATED CONTAINERS AND OLD NEWSPRINT AS A COMPONENT OF THE FURNISH FOR MULTIWALL SACKS

Project 3756

A Progress Report

to

THE KRAFT AND PACKAGING PAPERS DIVISION

OF THE

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August 10, 1994

SUMMARY

The effect of replacing kraft pulp with old newsprint and old corrugated containers is reported. We made handsheets on a laboratory sheet mold equipped for white water recirculation. This system allowed us to retain fines in the handsheets and simulated the white water conditions found on a commercial paper machine. We developed strength by refining the pulp, and we did not use additives in the sheetmaking process. The strength properties important in the manufacture of multiwall sacks are tensile, tear, and tensile energy absorption. We used Rule 40 to calculate the tensile index for handsheets that are equivalent to machine made multiwall paper. The required tensile index is 55 Nm/g. We found that kraft, OCC, and ONP pulps could be refined to this tensile strength. Of course, the freeness of OCC and ONP at this strength is much lower than that for kraft pulp.

We found that additional basis weight was needed to make sheets from OCC and ONP that had the same tear and tensile energy absorption as sheets made from kraft pulp. We used the handsheet strength data to develop regression equations to calculate the amount of overweight needed to make multiwall paper. As an example, a 25% substation of kraft with OCC requires 10% additional basis weight to maintain tear strength and 19% additional basis weight to maintain tensile energy absorption. If ONP is substituted, 50% additional basis weight is needed to maintain tear strength and 48% additional basis weight is required to maintain tensile energy absorption.

Porosity and optical properties must be considered in the manufacture of multiwall. We found that Gurley porosity will increase when OCC and ONP are substituted for kraft pulp. The amount of the increase will depend on the overweight and refining required to maintain strength. We report the optical properties for both luminous reflectance and the Hunter L*a*b* scales.

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INTRODUCTION

Paper manufacturers are responding to the solid waste problem by increasing the recycled fiber content of paper products. The products that offer the most immediate opportunity are packaging grades. These grades have strength and appearance requirements, but they do not have the stringent appearance and optical requirements of printing and writing grades. The paper industry has considerable experience in using recycled fiber in newsprint, corrugated medium, and linerboard. The use of recycled fibers in paper grades is not extensively practiced and no systematic laboratory studies have been reported. Several mills are using recycled pulp in small bags and grocery bags. These initiatives have been successful in producing a marketable product. However, the impact of recycled paper on strength properties and on machine productivity has not been reported. The use of recycled paper in multiwall grades has not been reported. This report describes a laboratory study sponsored by the American Forest and Paper Association, AFPA.

The objective of this study is to determine the impact of old newsprint (ONP) and old corrugated containers (OCC) on product performance and machine runnability of multiwall sack and bag grades of paper. The approach we used is based on the model of paper strength proposed by D. H. Page (1) and described in a previous publication (2). The pulp properties important for tensile strength development are fiber strength, perimeter, coarseness, length, and specific bond strength. The important paper property is relative bonded area. The relationship between these variables and the tensile strength of a paper sheet is given by **Equation 1**. In this study, we characterized kraft, ONP, and OCC pulp. Several of the important parameters in the Page equation and the measured strength properties of handsheets are used to access the impact of recycled fiber on the strength of sheets made from blends of the three pulps. The Page equation teaches that the tensile strength of a paper sheet depends on two independent terms. The first term in **Equation 1** contains only the fiber strength. This term is numerically equivalent to the highest tensile strength possible for any type of pulp. In practice, this term accounts for about 50% of the tensile strength of a handsheet or piece of machine-made paper.

$$1/T = 9/8Z + 12gC/PLbRBA \quad (1)$$

where:

T = sheet tensile strength, km;
Z = zero span tensile strength, km;
P = fiber perimeter, microns;
C = fiber coarseness, mg/100m;
L = third moment fiber length, mm;
b = specific fiber-fiber bond strength, dynes/cm^2;
RBA = relative bonded area, percent;
g = gravitational constant.

The second term is more complex and contains parameters that characterize the contribution of fiber geometry and fiber-fiber bonding to sheet strength. In this paper, we will concentrate on the fiber length term, L. The tensile strength of the sheet will decrease as fiber length decreases. We expect refining to cause the fiber length to decrease and since ONP will have a much lower fiber length than kraft or OCC pulps, we expect this parameter to be important.

EXPERIMENTAL

The kraft pulp used in this study was a commercial 50 Kappa southern pine multiwall pulp. The ONP was a commercial newsprint containing about 25% recycled fiber. OCC pulp was simulated by blending 25% of a commercial corrugating medium made by the green liquor process with 75% virgin kraft southern pine linerboard. The RBA of the sheet was changed by refining the pulps in a valley beater. This study consisted of nine experiments that are listed in **Table I**. The mixture combinations were chosen to simulate the most likely combinations that will occur in the manufacturing of bag and sack paper.

I. The experimental design used to study the effect of recycled fibers on the strength of paper grades used for packaging.

EXPERIMENT NUMBER	PERCENT ONP	PERCENT OCC	PERCENT KRAFT
1	100	----	----
2	----	100	----
3	----	----	100
4	15	15	70
5	30	----	70
6	----	30	70
7	25	25	50
8	50	----	50
9	----	50	50

Handsheets were prepared in a British sheet mold equipped with a system to recycle the white water. This system allows us to account for the effect of fines on sheet properties, an important issue in the use of recycled fiber. The amount of fines retained in the sheet will contribute to retardation of paper machine drainage, as well as paper strength and optical properties. The handsheets were restrained between blotters and dried on a steam dryer to a moisture content of about 6%. Sheet properties were measured using TAPPI methods (3). Fiber length was measured by Bauer MacNett classification (4).

FIBER PROPERTIES

Fiber Strength

The zero span tensile strengths of the pulps used in these studies are given in **Table II**. The value of the kraft pulp is similar to the value we have measured in other studies (2). The strength of the OCC is 12% lower than the virgin kraft. This value is similar to our previous measurements (2).

The strength of the ONP is 26% lower than kraft pulp and 16% lower than OCC pulp. This is the first measurement we have made of the fiber strength of a newsprint furnish in our laboratory. We do not know if lower fiber strength is a general condition for newsprint furnishes. These differences are significant and should be observable in the manufacturing process. The zero span tensile strength contributes about 50 % of the strength of paper made from chemical pulp. Therefore, if the second term in **Equation 1** is held constant when recycled ONP is substituted for kraft, we expect a minimum 13% decrease in the tensile strength of the sheet. Additional refining will be required to develop a tensile strength equivalent to a kraft sheet.

II. The zero span tensile index was not a function of refining. The difference between pulps is statistically significant.

Pulp Type	Zero Span Nm/g	Standard Deviation Nm/g
Old Newsprint	110.5	7.2
Old Corrugated Containers	131.5	8.3
Virgin kraft	149.5	8.3

Fiber Length

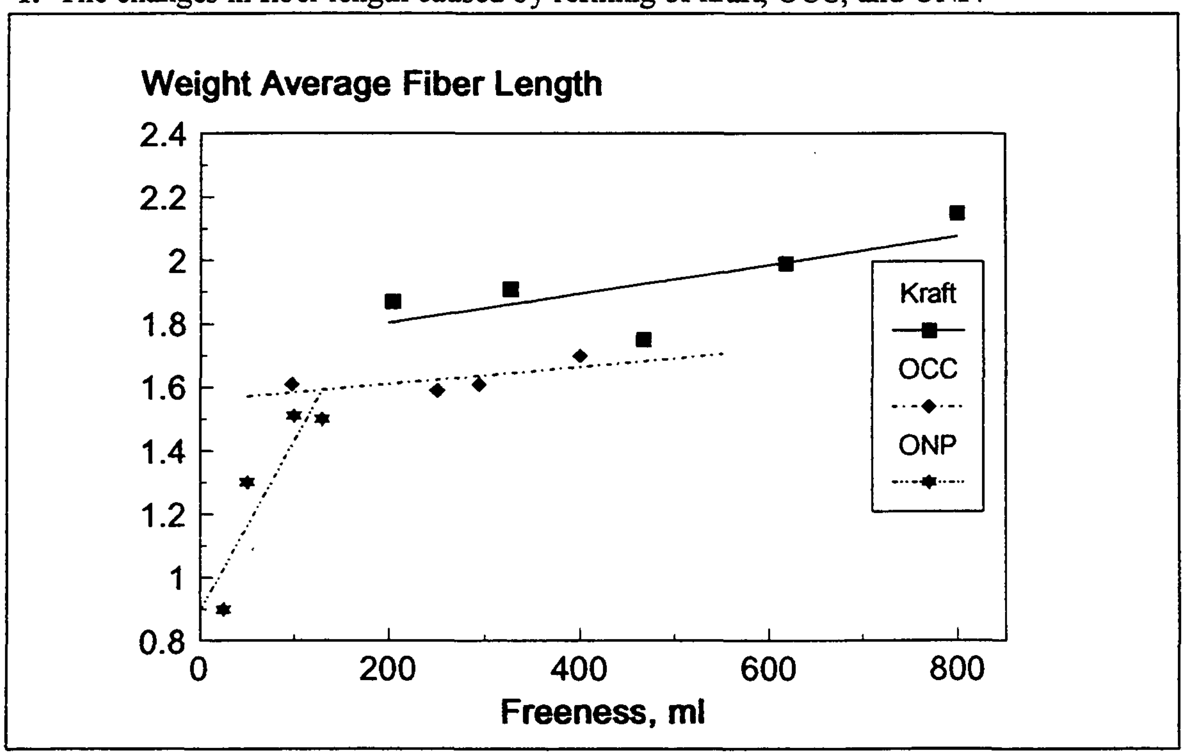
We used the Bauer-McNett method to measure the fiber length, and the results were plotted in **Figure 1**. The lines for the kraft pulp and the OCC are nearly parallel. This result supports our earlier report that refining recycled pulp does not produce fiber cutting which is different from virgin kraft pulp (2). This result suggests that the strength loss often observed for recycled pulp is not due to a reduction in fiber length of the recycled chemical pulp. The relationship between fiber length and freeness for ONP has a much steeper slope compared to the kraft and OCC curves. These results warn us that refining strategies must be carefully thought out and controlled when ONP is part of the furnish. Lowering the freeness of the ONP pulp will reduce the drainage on the paper machine that can result in reduced production.

STRENGTH PROPERTIES

The Effect Of Refining On Strength Properties

The major strength properties for multiwall sack grades are tensile, burst, tear, and tensile energy absorption (TEA). The relationship between these properties and freeness are shown in **Figure 2**, **Figure 3**, **Figure 4**, and **Figure 5**. To develop a strategy for producing a satisfactory paper product, we must first choose a strength property that can act as a reference. In the case of multiwall sacks, the logical strength property to chose is tensile strength. Rule 40 specifies the level of tensile strength required to make an acceptable multiwall sack (5). To use the values specified in Rule 40, we must first convert the MD and CD tensile strength values into an equivalent strength for handsheets. This conversion can be made by taking the square root of the product of the values given in Rule 40. Using the values in Rule 40, we arrive at a target value of the tensile strength of 55 Nm/g.

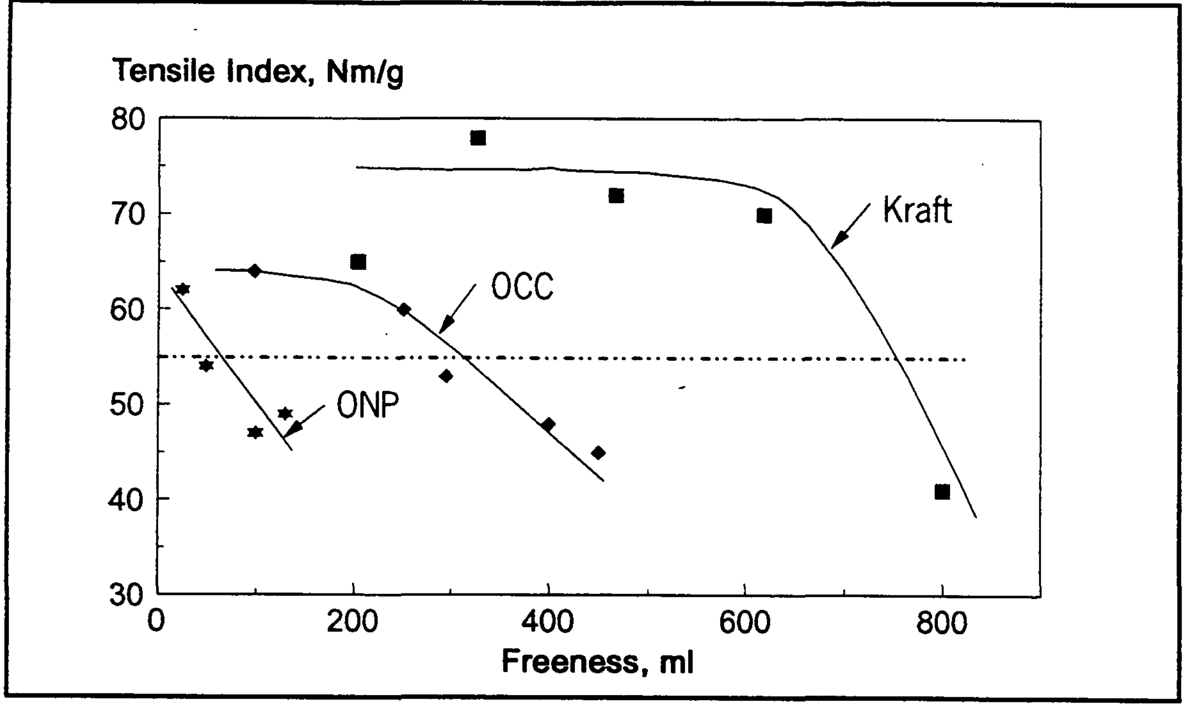
1. The changes in fiber length caused by refining of kraft, OCC, and ONP.



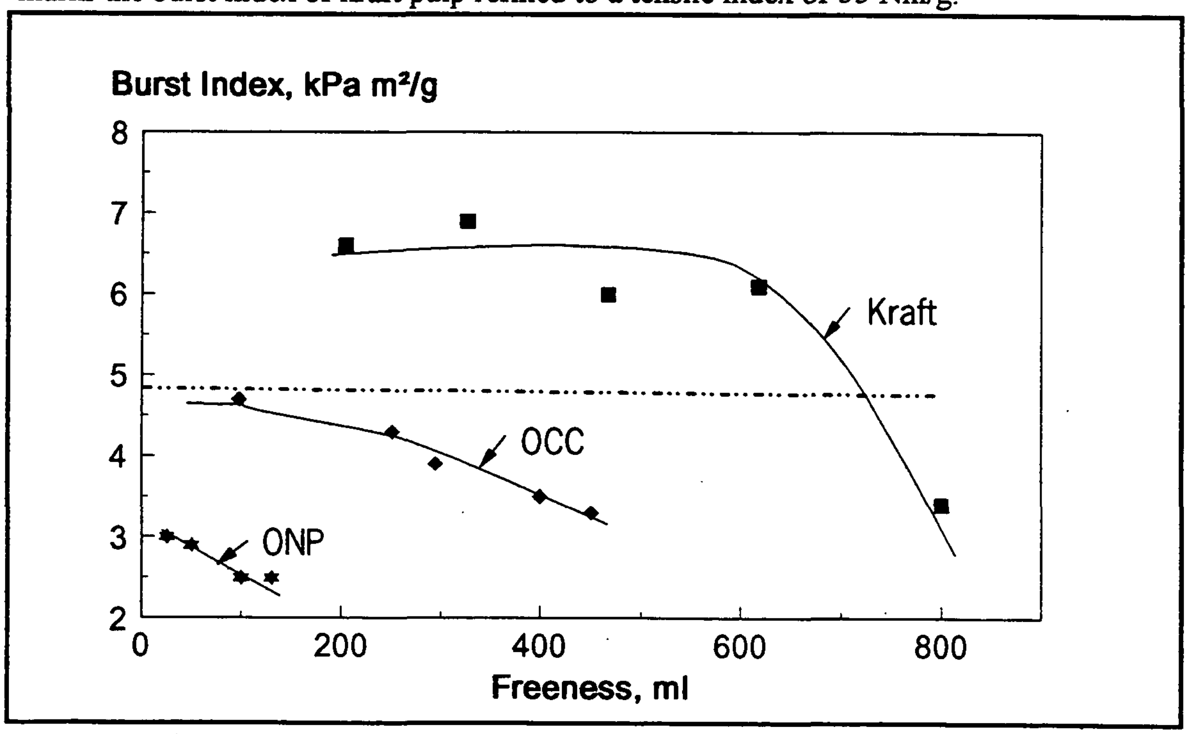
Regression information for Figure 1. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	1.71	.00045	52
OCC	1.55	.00026	47
ONP	.89	.00535	79

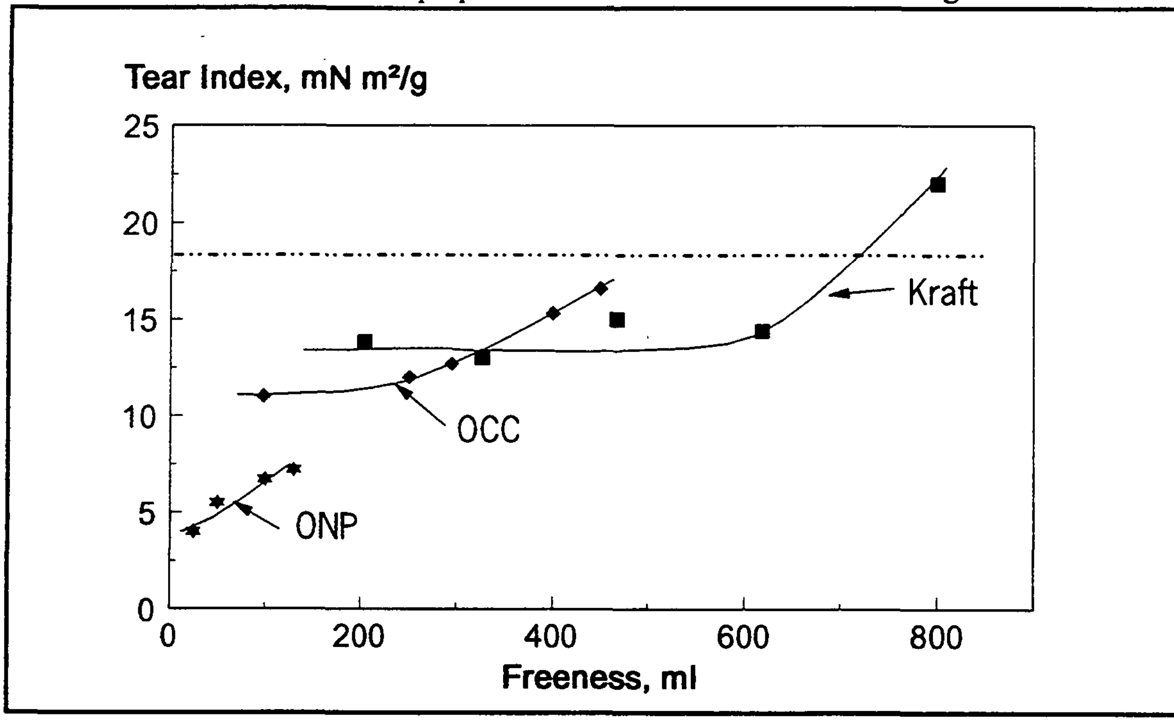
2. Refining curves of tensile index for the pulps used in this study. The horizontal line marks the tensile index value of 55 Nm/g.



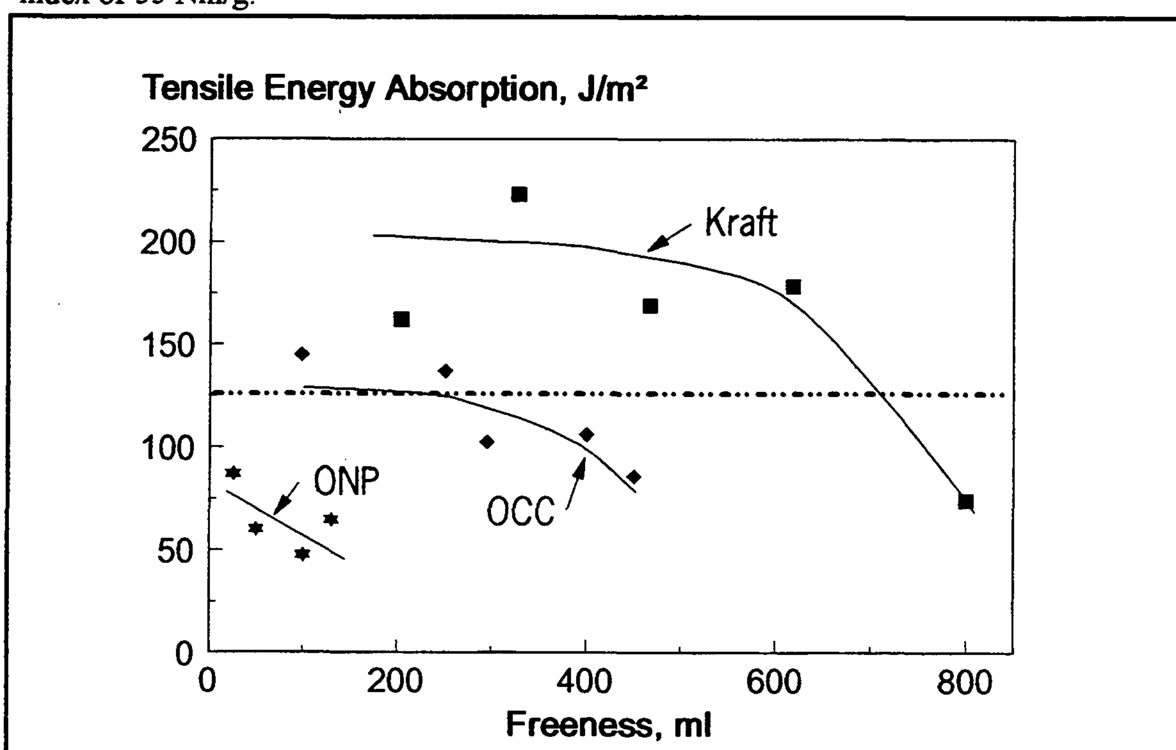
3. Refining curve of burst index for the pulps used in this study. The horizontal line marks the burst index of kraft pulp refined to a tensile index of 55 Nm/g.



4. Refining curves of tear index for the pulps used in this study. The horizontal line marks the tear index of a kraft pulp refined to a tensile index of 55 Nm/g.



5. Refining curves of tensile energy absorption for pulps used in this study. The horizontal line marks the tensile energy absorption for a kraft pulp refined to a tensile index of 55 Nm/g.



In **Figure 2,** the dashed line shows the target tensile strength needed to produce an acceptable multiwall product. This line allows us to compare the kraft pulp to the OCC and ONP pulps. In **Figure 2,** the dashed line intersects the curves for both the OCC and the ONP. This means that if tensile strength were the only important strength property any of the three pulps could be used to make an acceptable product. This is not true for burst, tear, or tensile energy absorption. In **Figure 3**, **Figure 4**, and **Figure 5,** the dashed line does not intersect the OCC or ONP curves. Therefore, these pulps will not produce a sheet equivalent to kraft pulp when refining is the only tool used to develop strength.

Strategies To Achieve The Required Strength For Multiwall Sacks

Refining is the principle tool used by papermakers to develop the strength properties of fibers and to achieve the required strength characteristics of the paper sheet. We showed in the preceding section that refining alone was not a sufficient tool to develop sheet strength. Therefore, another tool must be employed by the papermaker. The use of adhesives and the use of additional fiber mass are two commonly used tools. Adhesives will increase the tensile, burst, and tensile energy absorption. However, tear strength is inversely related to tensile strength; therefore, the use of adhesives to increase tensile strength will decrease tear strength. Multiwall sacks are required by Rule 40 to maintain specified levels of tensile strength and tear strength. Therefore, overweight will be required to produce common multiwall paper subject to shipping regulation. The following sections address the amount of overweight that must be added to the sheet.

The exact amount of overweight added to the sheet will depend on the strength property under consideration. However, the calculation of overweight will be the same for all the strength properties. Since the tensile strength can be achieved through refining, we will use this property as the reference. The target tensile index is 55 Nm/g for a random handsheet. First, we make a plot of the strength property of interest versus tensile index. Then, we fit the data using regression techniques. Usually, a liner or exponential equation will fit the data. Finally, we calculate the strength at a tensile index of 55 Nm/g. The overweight required to achieve the strength equivalent to a pure kraft pulp is given in **Equation 2.**

$$\%\ \text{Overweight} = [(\text{kraft}-V)/V] \times 100 \qquad (2)$$

where:

kraft = the strength of a pure kraft sheet at a tensile index of 55 Nm/g;
V = the strength of a sheet containing substitute pulp at a tensile index of 55 Nm/g.

The percentage overweight computed with **Equation 2** can be used by the papermaker to adjust the sheet basis weight to overcome a weakness resulting from pulp substitution.

The overweight strategy for burst strength. We plotted the relationship between burst index and tensile index in **Figure 6** and **Figure** 7. The data can be represented with a linear relationship, and the parameters of the fit are given in each figure. The data for mixtures of kraft and OCC pulp shown in **Figure 6** is scattered. This leads to a set of regression equations that do not have nearly parallel slopes. The data for mixtures of kraft and ONP pulp is better behaved and shows the behavior expected for this type of plot. We can smooth the data by construction lines of similar slope through the mean of each data set. Since we intend to use calculations from the regression equation in another regression, we chose to allow the error to accumulate and use the true regression equation for the percentage overweight calculation. This approach allows the scatter to be smoothed in the overweight calculation. We plotted the data for mixtures of kraft, OCC, and ONP pulp in **Figure 8**. The data for 25% OCC, 25% ONP and 50% kraft covers a small range of tensile index. Therefore, the slope of the regression line is not parallel to the mixture containing the 70% kraft. We have chosen to use the regression data and include to scatter in the calculation of the percentage overweight.

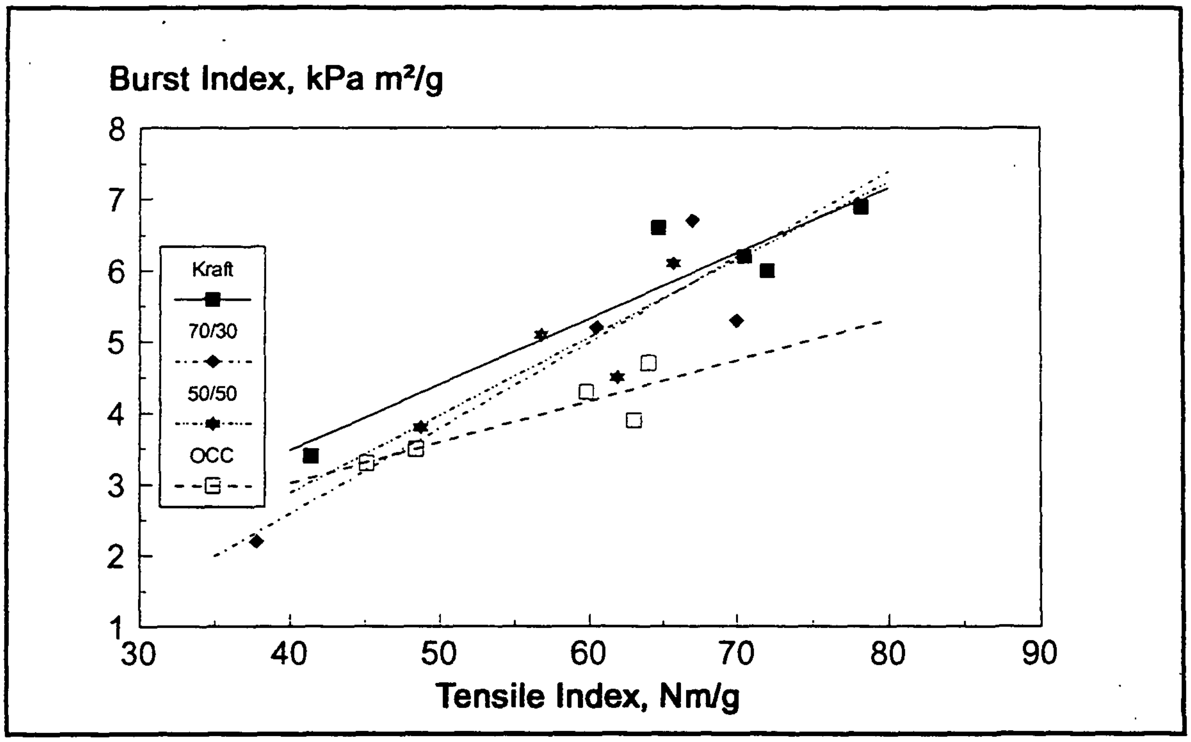
In **Figure 9,** we plotted the burst index at a tensile index of 55 Nm/g verus the percentage kraft pulp in the sheet. The regression equation is linear, and the R^2 value for both sets of data is high. Therefore, we are justified in using a linear relationship for the relationship between percentage overweight and percentage kraft. This relationship is shown in **Figure 10**. The equation for calculating the percentage overweight required to achieve a bust index equal to a pure kraft sheet is given in **Figure 10**. The general form of the equation is given in **Equation 3.**

$$\% \text{ Overweight} = \{a[Pa/(Pa+Pb)] + b[Pb/(Pa+Pb)]\}(1-Pk/100) \quad (3)$$

where:
a = strength index for pure pulp a;
b = strength index for pure pulp b;
Pa = percentage pulp a in the sheet;
Pb = percentage pulp b in the sheet;
Pk = percentage kraft pulp in the sheet.

The overweight strategy for tear strength. The analysis of tear strength is similar to the analysis for burst strength. We plotted tear index versus tensile index in **Figure 11** and **Figure 12**. The data can be represented by an exponential equation. The constants for the regression are given in the figures. We plotted the relationship between tear index and the percentage kraft in **Figure 13**. The data can be represented by a linear fit. The perimeters of the regression are given in the figure. This regression is converted in the graph shown in **Figure 14.** The equation for calculating the percentage overweight for a mixture of three pulps is given in the same figure.

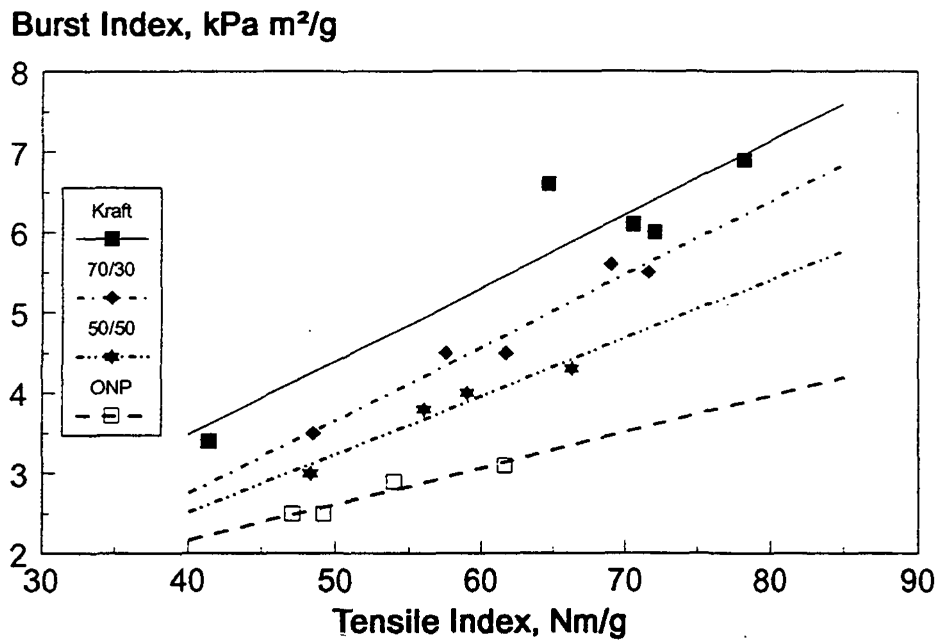
6. Burst index can be represented as a linear function of tensile index for kraft and OCC pulps. The data for mixtures lie between the lines for the pure pulps. However, the data for mixtures are scattered.



Regression information for Figure 6. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	-.19	.092	.88
70% Kraft/30% OCC	-2.22	.12	.85
50% Kraft/50% OCC	-1.49	.11	.68
OCC	.715	.057	.77

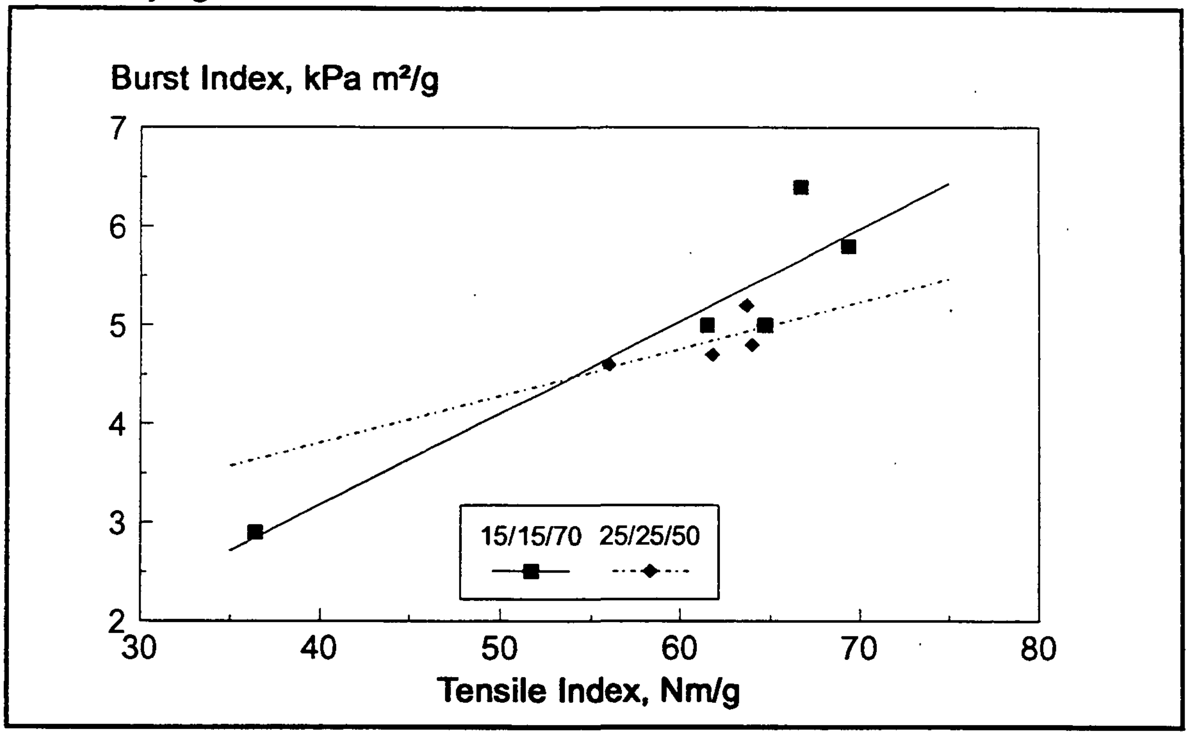
7. Burst index can be represented as a linear function of tensile index for kraft and ONP pulps. The data for mixtures lie between the lines for the pure pulps.



Regression information for Figure 7. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	-.17	.09	.87
70% Kraft/30% ONP	-8.8	.09	.95
50% Kraft/50% ONP	-.38	.07	.94
ONP	.37	.04	.93

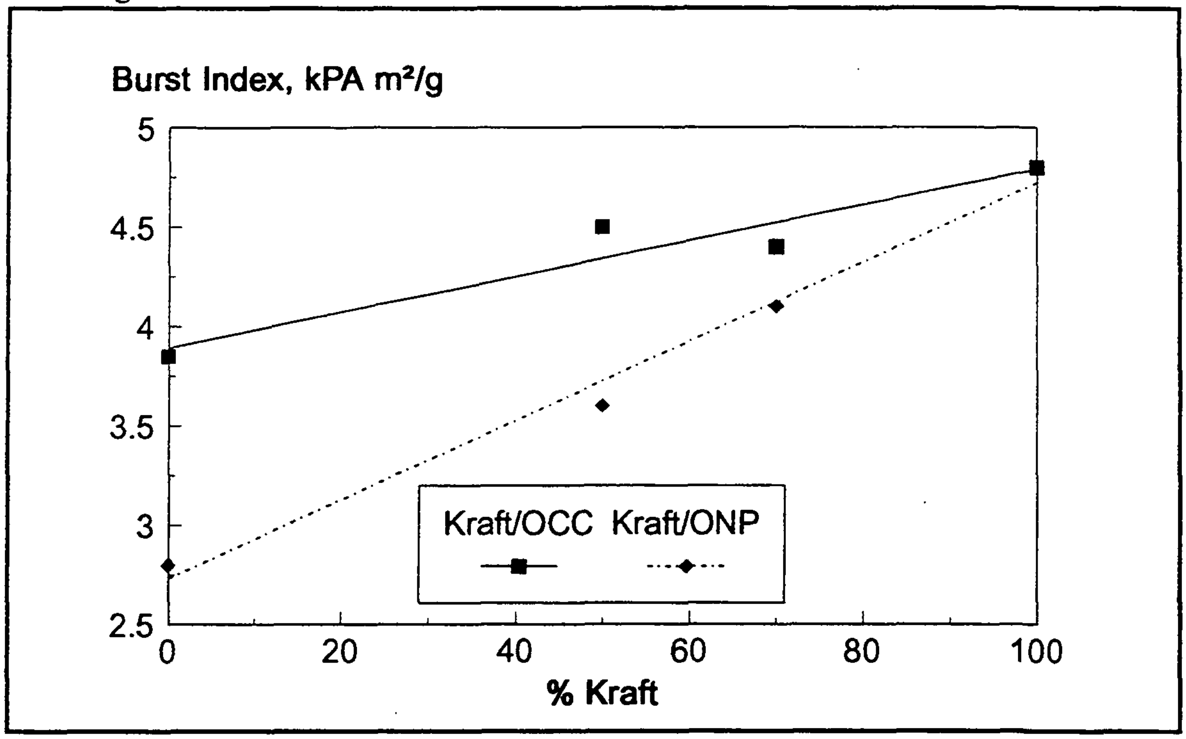
8. The burst index for mixtures of three pulps can be represented as a linear function of tensile index. The data for the mixture 25% OCC, 25% ONP, and 50% kraft are limited in its range. Therefore, the apparent difference in the slopes of the two lines is not statistically significant.



Regression information for Figure 8. Equation: Y=a+bX.

Pulp	a	b	R^2
%OCC/ONP/Kraft 15/15/70	1.91	.047	45
%OCC/ONP/Kraft 25/25/50	-.54	.09	88

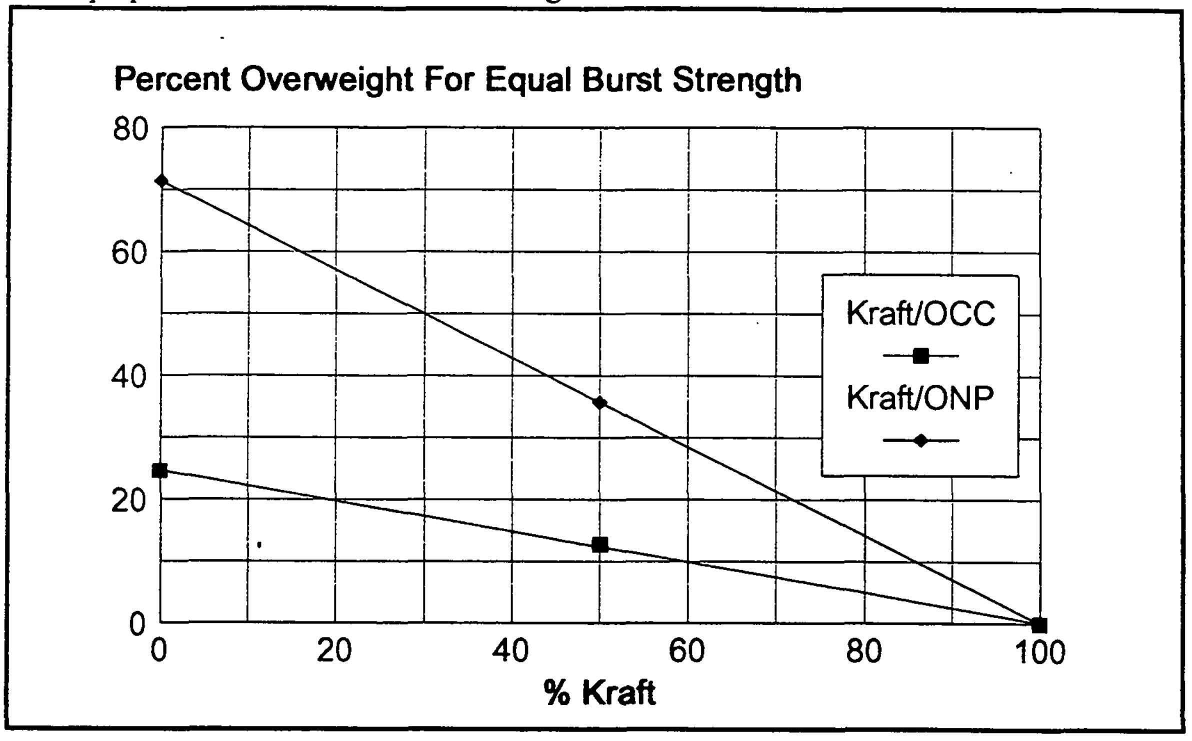
9. The relationship between burst index and the kraft content of a sheet can be represented by a linear function. This relationship is for sheets with a tensile index of 55 Nm/g.



Regression information for Figure 9. Equation: Y=a+bX

Pulp	a	b	R^2
Kraft/OCC mixtures	3.89	.009	91
Kraft/ONP mixtures	2.73	.02	99

10. This figure shows the overweight required to develop a burst strength equivalent to a kraft pulp with a tensile index of 55 Nm/g.

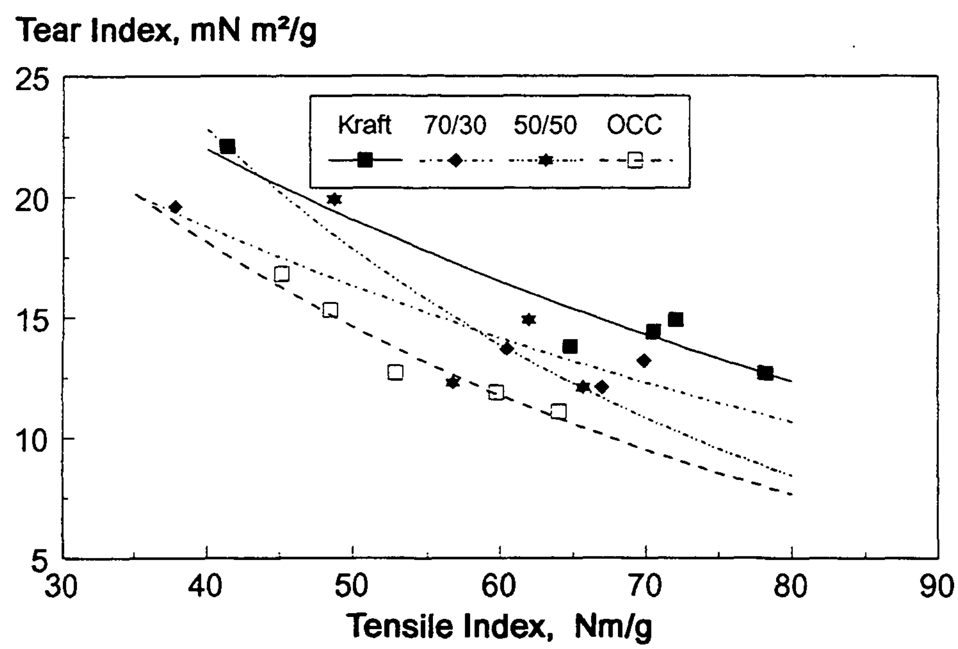


% Overweight = {24.6×[Pa(Pa+Pb)]+71.4×[Pb/(Pa+Pb)]}×(1-Pk/100)

where:

Pa = percentage OCC in the sheet;
Pb = percentage ONP in the sheet;
Pk = percentage Kraft in the sheet.

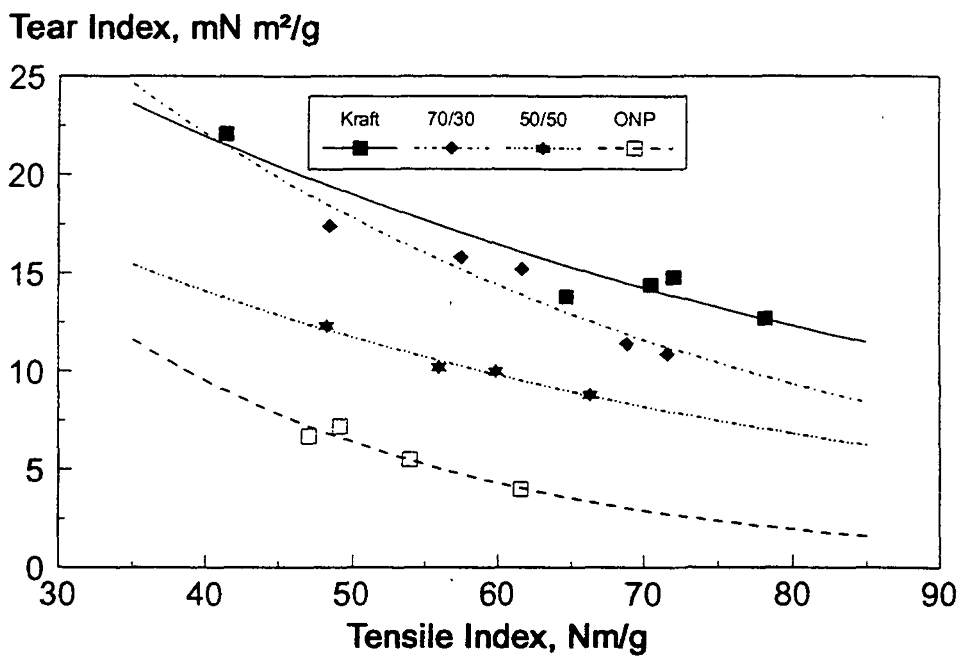
11. Tear index can be represented as an exponential function of tensile index for kraft and OCC pulps.



Regression information for Figure 11. Equation: Y= a×exp(bX).

Pulp	a	b	R^2
Kraft	39.1	-.01	90
70% Kraft/30% OCC	33	-.014	93
50% Kraft/50% OCC	61.8	.025	62
OCC	42.7	-.02	93

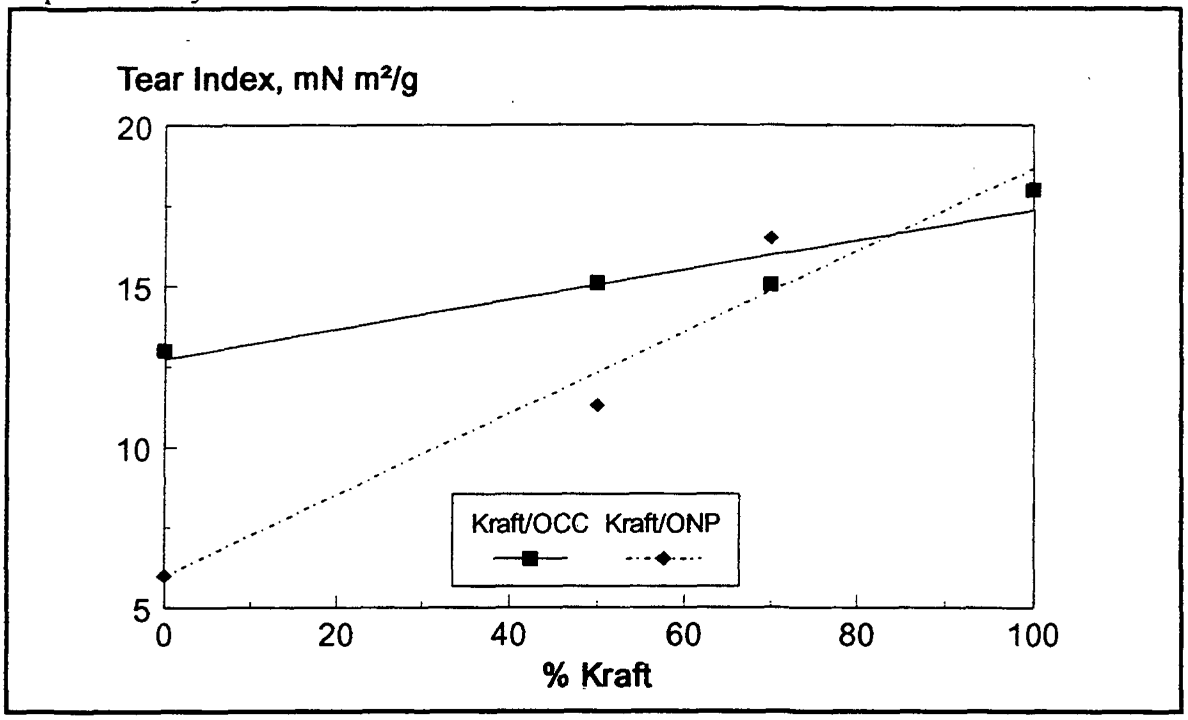
12. Tear index can be represented as an exponential function of tensile index for kraft and ONP pulps.



Regression information for Figure 12. Equation: Y= a×exp(bX).

Pulp	a	b	R^2
Kraft	39.1	-.014	91
70% Kraft/30% ONP	52.2	-.021	91
50% Kraft/50% ONP	29	-.018	97
ONP	46.6	-.04	94

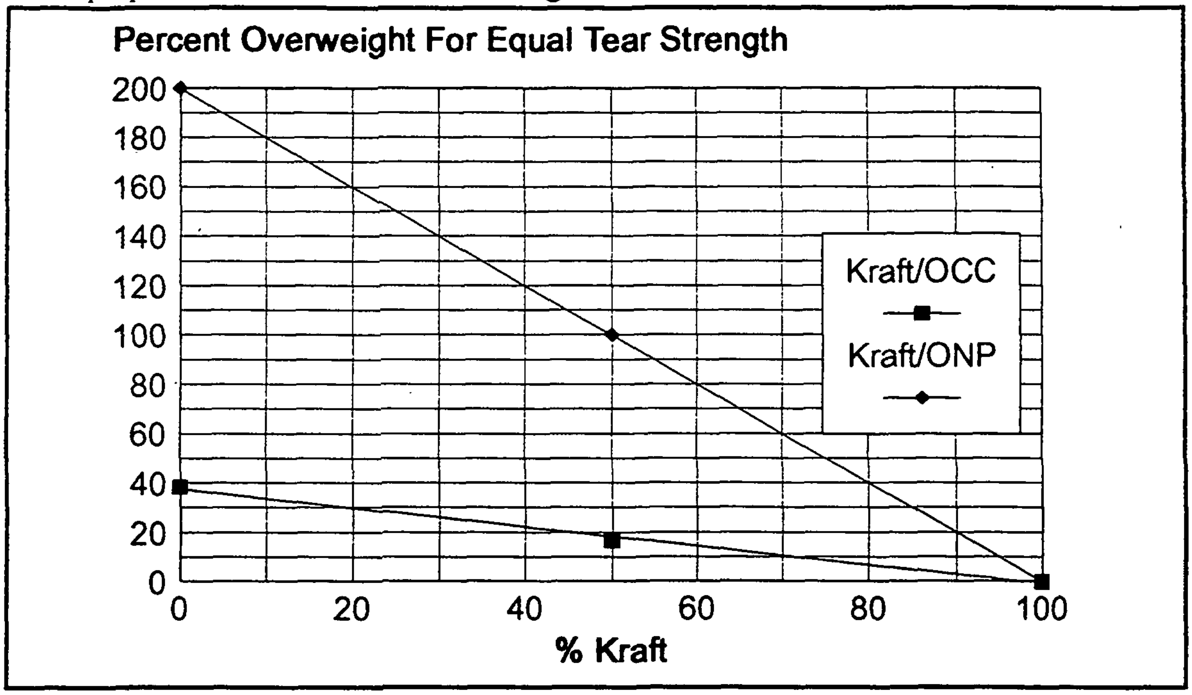
13. The relationship between tear index and the kraft content of the sheet can be represented by a linear function.



Regression information for Figure 13. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft/OCC mixtures	12.7	.046	89
Kraft/ONP mixtures	5.99	.127	95

14. This figure shows the overweight required to develop a tear strength equivalent to a kraft pulp with a tensile index of 55 Nm/g.



% Overweight = {38.5×[Pa/(Pa+Pb)]+200×[Pb/(Pa+Pb)]}×(1-Pk/100)

where:

Pa = percentage OCC in the sheet;
Pb = percentage ONP in the sheet;
Pk = percentage Kraft in the sheet.

The overweight strategy for tensile energy absorption. The tensile energy absorption is not a requirement for flat kraft grades covered under Rule 40. However, this property is important for end-use performance of multiwall sacks. We plotted the relationship between tensile energy absorption and tensile index in **Figure 15** and **Figure 16.** Tensile energy absorption is by definition a linear function of tensile index. Therefore, we expect the linear relationship shown in the figures. Inspection of the figures reveals that the tensile energy absorption will not be linearly related to the percentage kraft in the sheet. The effect is best observed in **Figure 16**. The mixtures of kraft and ONP are clustered around the line for pure ONP pulp. This behavior suggests that the tensile energy absolutions will decrease rapidly as kraft pulp is removed from the sheet.

This result suggests that stretch is a nonlinear function of percentage kraft in the sheet. We plotted stretch versus tensile index in **Figure 17** and **Figure 18**. Inspection of these figures shows that stretch is a nonlinear function of percentage kraft in the sheet. We believe that the nonlinear relationship observed between tensile energy absorption and the percentage kraft in the sheet is a result of the nonlinear behavior of stretch. The papermaker has several devices to affect the stretch of the sheet. He can reduce the draws in the paper machine thus increasing MD stretch. He can allow greater shrinkage in the dryer section thus increasing the CD stretch. Both of these actions will result in an increase in the tensile energy absorption and could be used to overcome the overweight requirement calculated in the next section.

We plotted the relationship between tensile energy absorption and percentage kraft in **Figure 19.** The nonlinear effects can be clearly seen in this figure. We plotted the graph for percentage overweight in **Figure 20**. We have not attempted to fit this data because of the nonlinear relationship. The percentage overweight can be estimated directly from **Figure 20**.

POROSITY

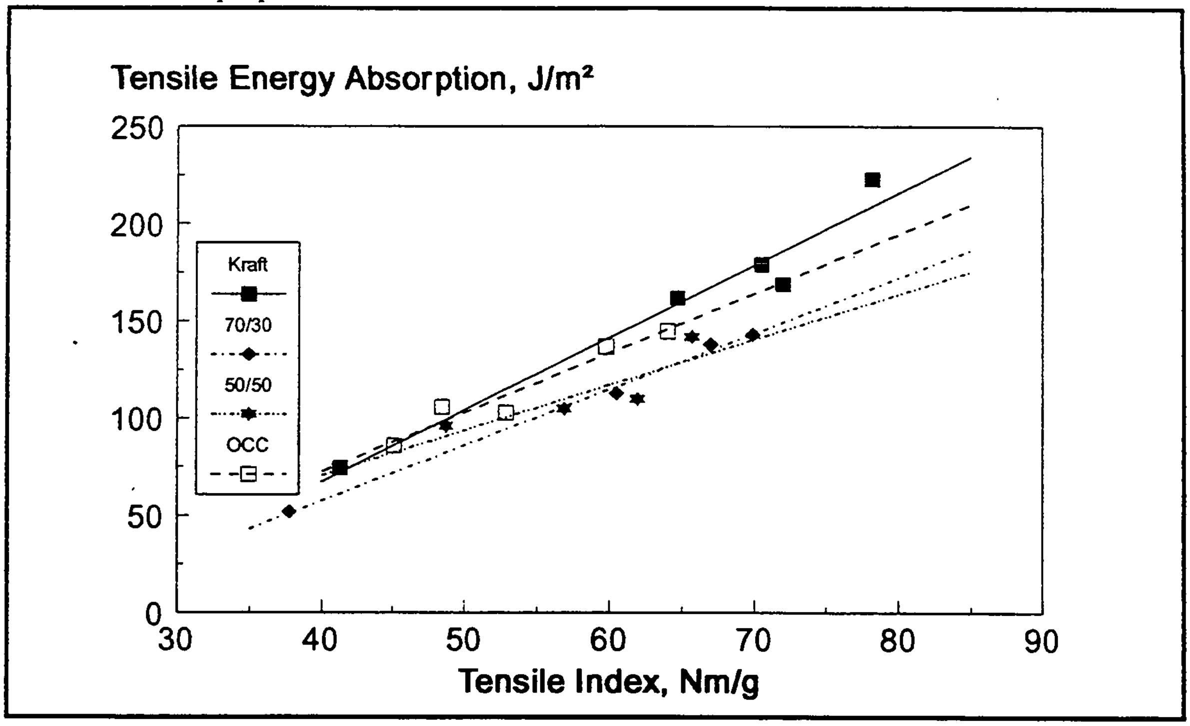
Air must be released from multiwall bags during the filling process. Generally, bags are perforated to allow for the air removal. However, many customers believe that the porosity of the sheet is important to control air release. **Figure 21** and **Figure 22** show the relationship between tensile index and porosity. The effect of OCC will be minimal up to 25% substitution. However, the ONP effect will be observed with low levels of substitution.

OPTICAL PROPERTIES

Luminous Reflectance

The TAPPI method for luminous reflectance is used to control the appearance of multiwall paper. We plotted luminous reflectance versus tensile index in **Figure 23** and **Figure 24**. The coefficients of the linear regression are given in the figures. Luminous reflectance decreased as the tensile index increased.

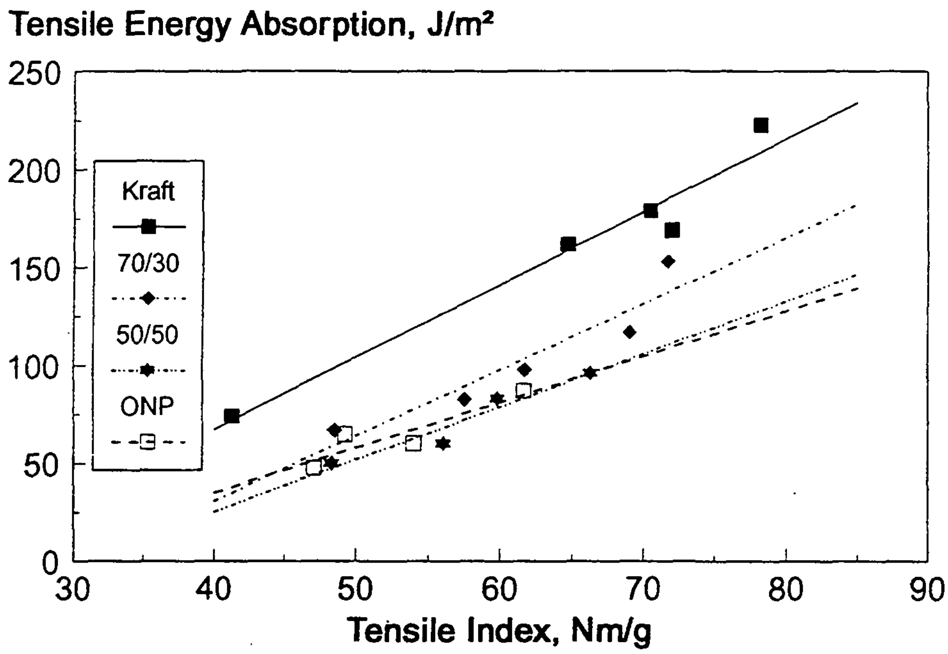
15. Tensile energy absorption can be represented as a linear function of tensile index for kraft and OCC pulps.



Regression information for Figure 15. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	-81.1	3.71	96
70% Kraft/30% OCC	-57.3	2.87	99
50% Kraft/50% OCC	22.6	2.33	73
OCC	-49.6	3.05	93

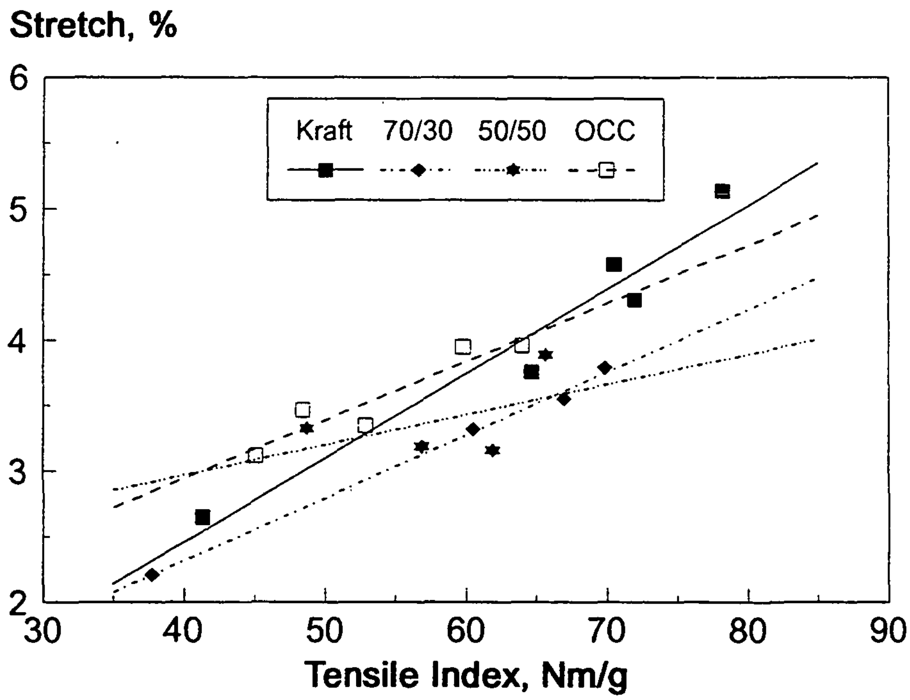
16. Tensile energy absorption can be represented as a linear function of tensile index for kraft and ONP pulps.



Regression information for Figure 16. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	-81.1	3.7	96
70% Kraft/30% ONP	-104.1	3.4	88
50% Kraft/50% ONP	-82.7	2.7	93
ONP	-58.9	2.3	82

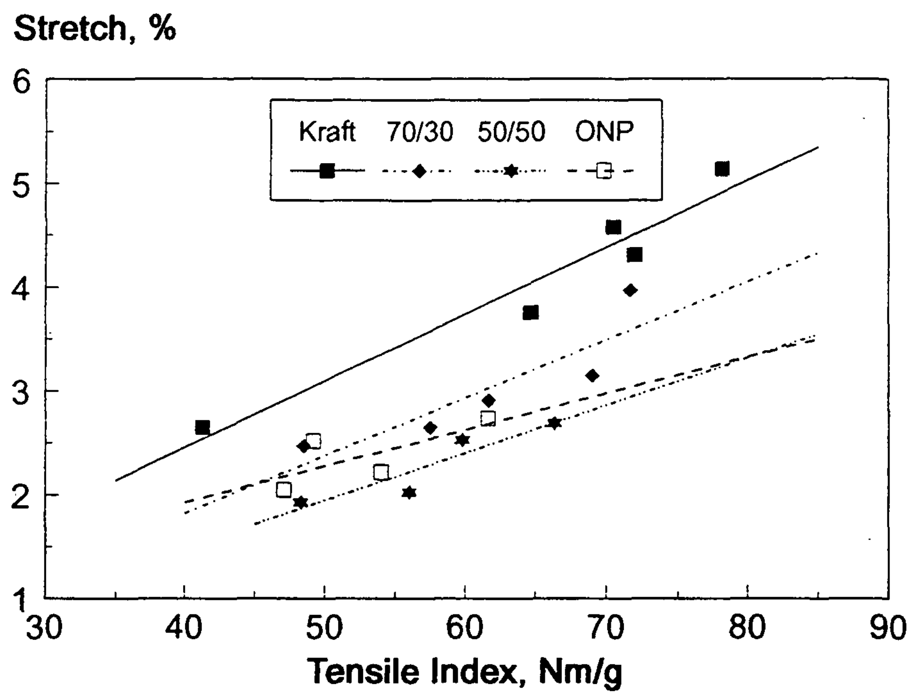
17. Stretch can be represented as a linear function of tensile index. However, this relationship is nonlinear with sheet composition.



Regression information for Figure 17. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	-.109	.064	94
70% Kraft/30% OCC	.398	.048	99
50% Kraft/50% OCC	2.05	.023	.25
OCC	1.17	.044	.87

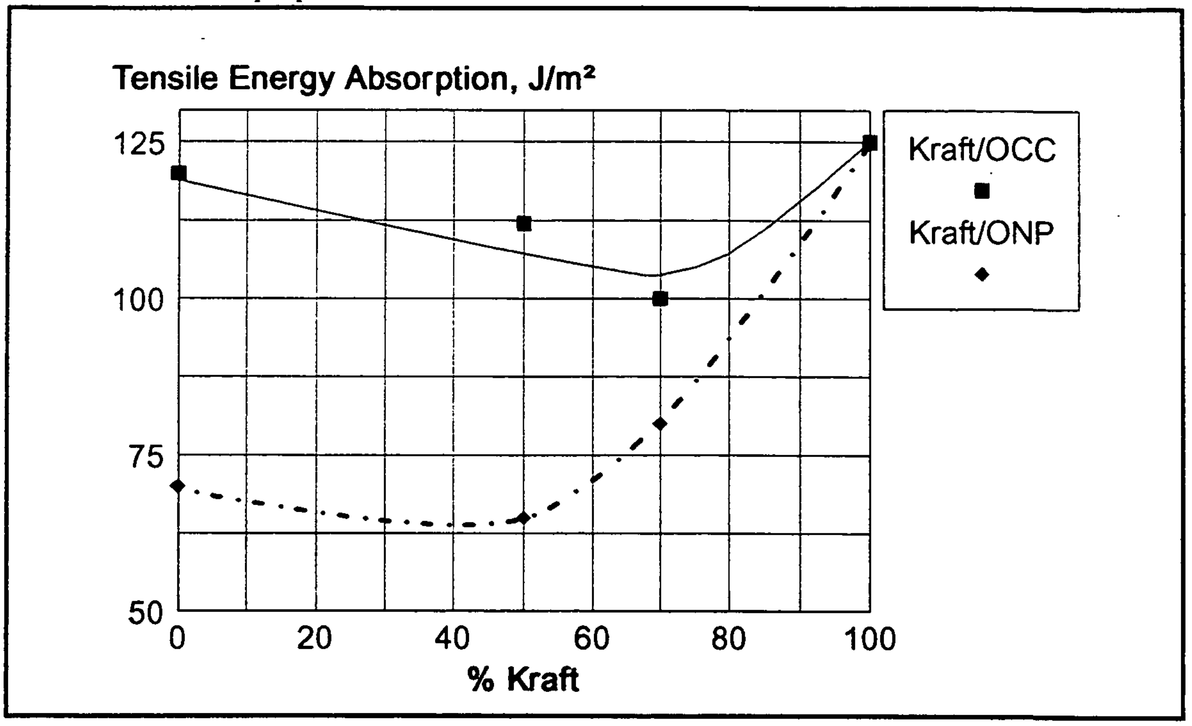
18. Stretch can be represented as a linear function of tensile index. However, the data are nonlinear in composition.



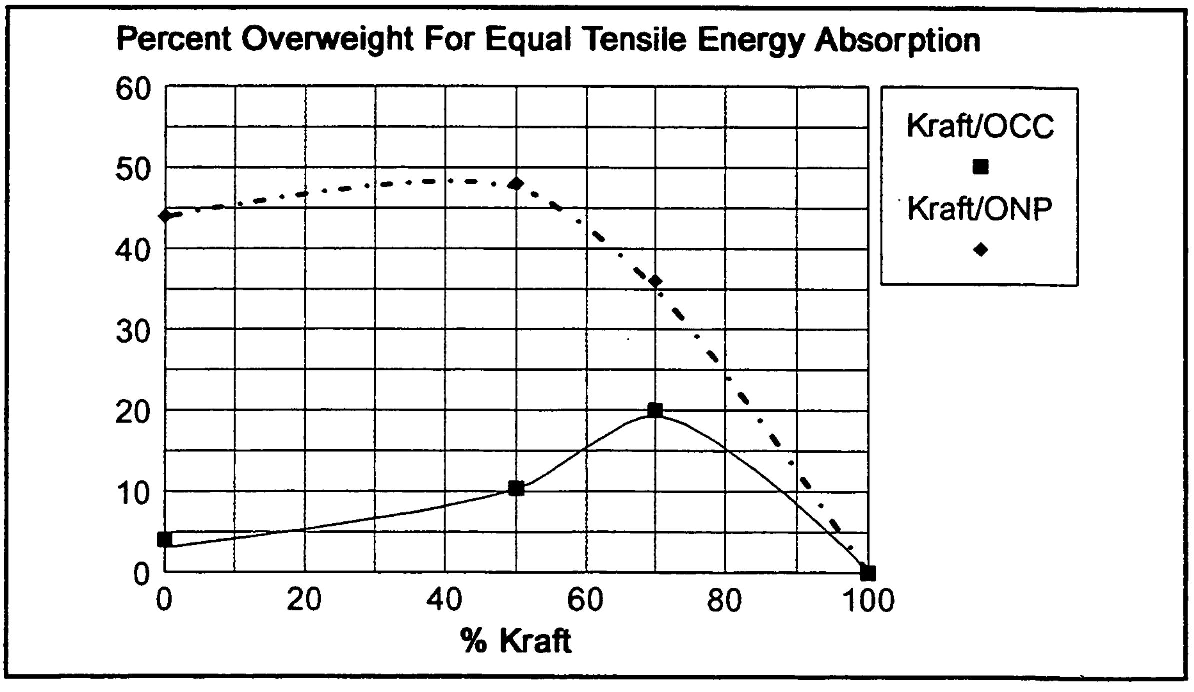
Regression information for Figure 18. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	-.108	.064	94
70% Kraft/30% ONP	-.412	.056	78
50% Kraft/50% ONP	-.344	.046	86
ONP	.527	.035	54

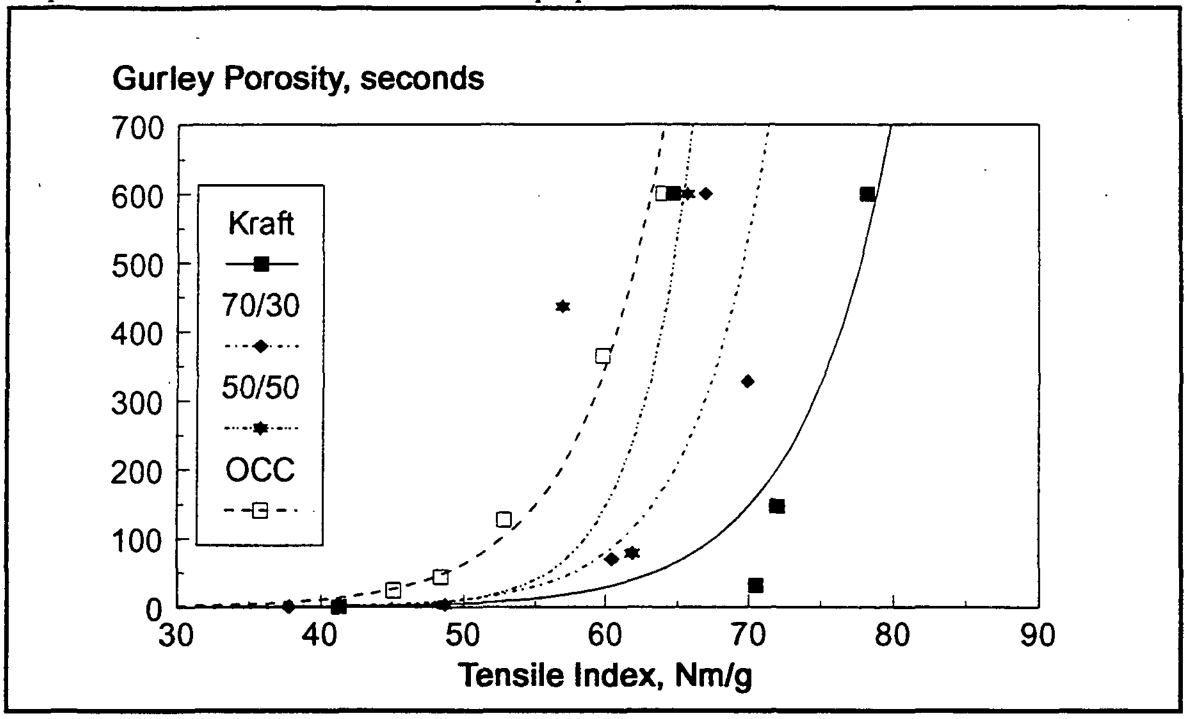
19. The relationship between tensile energy index and tensile index for mixtures of kraft and OCC or ONP pulp is nonlinear.



20. This figure provides a working graph to calculate the overweight required for mixtures to give tensile energy absorption equal to kraft pulp refined to 55 Nm/g tensile index.



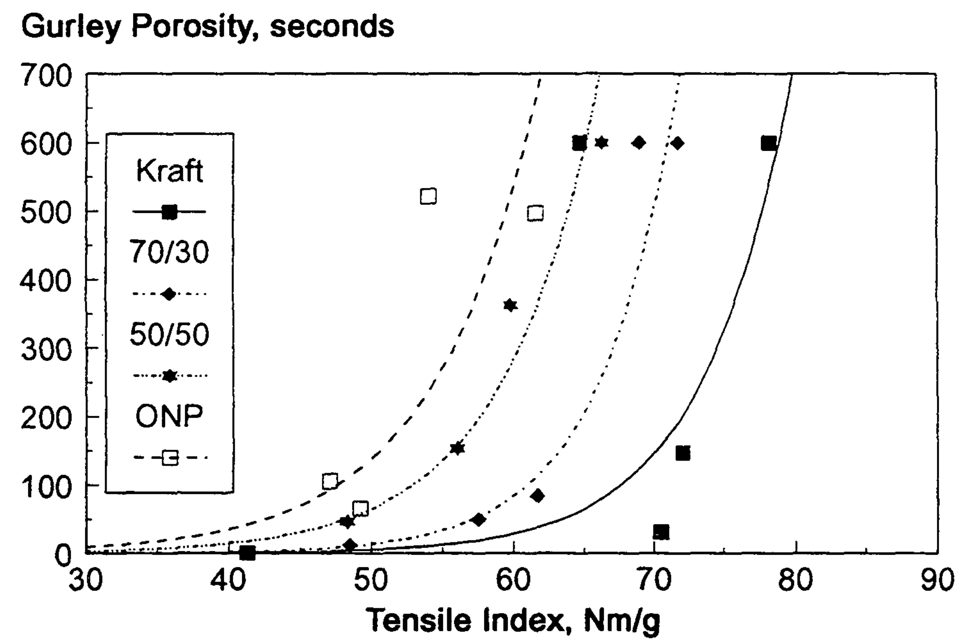
21. The relationship between Gurley porosity and tensile index can be represented by an exponential function for kraft and OCC pulp.



Regression information for Figure 21. Equation: $Y = a \times \exp(bX)$.

Pulp	a	b	R^2
Kraft	.002	.159	72
70% Kraft/30% OCC	.0008	.191	95
50% Kraft/50% OCC	.00002	.26	67
OCC	.011	.171	99

22. The relationship between Gurley porosity and tensile index can be represented by an exponential function for kraft and ONP pulp.



Regression information for Figure 22. Equation: Y=a×exp(bX).

Pulp	a	b	R^2
Kraft	.002	.159	72
70% Kraft/30% ONP	.00019	.178	98
50% Kraft/50% ONP	.044	.146	97
ONP	.163	.134	67

This behavior is expected and is observed in the production of machine-made papers. The relationship between luminous reflectance and the percentage kraft is plotted in **Figure 25**. The regression coefficients are also shown in this figure. Overweight is not an issue in determining the optical properties of sheets made from mixtures of pulps. Therefore, the relationship in **Figure 25** can be used directly to estimate the luminous reflectance of mixtures.

The L*a*b* scale. Another measure of appearance is the L*a*b* scale of color coordinates. **Figures 26, 27, 28, 29, 30, 31** show these coordinates as a function of tensile index. The L* value gives similar information to the luminous reflectance; i.e., ONP is "brighter." The a* and b* values are independent of the tensile index. However, they are dependent on the mixture of pulp used to make the sheet. The papermaker does not normally think in terms of this color coordinate system. If the use of many different pulp combinations becomes a necessity for making multiwall sacks, dyes will be required to maintain a color match to a natural kraft sheet. **Figure 32, Figure 33**, and **Figure 34** provide working graphs for developing a dye formulation for pulp mixtures.

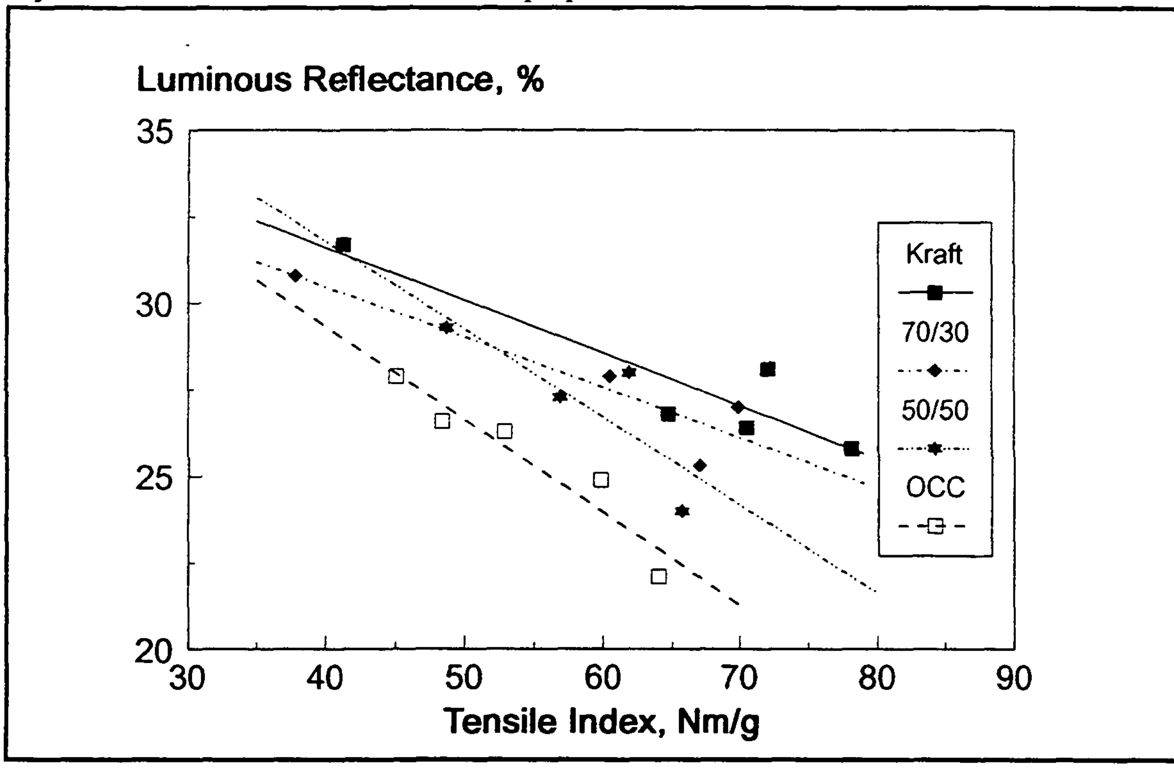
DISCUSSION

The results of the experiments described in the previous section make it clear that refining alone cannot produce a sheet that has satisfactory tensile, tear, TEA, and burst strength for multiwall paper. A possible strategy to make paper with satisfactory strength properties is to refine to a specified tensile strength and then use additional basis weight to achieve satisfactory tear, TEA, and burst properties. **Table III** gives the overweight required to make a sheet with satisfactory tear strength. Several levels of substitution are included in the table. OCC is a preferred substitute to ONP since in all cases the amount of overweight required to make satisfactory tear is less. If 25% of the kraft pulp is replaced by OCC, the required overweight is 10%. Whereas, if ONP is used, the required overweight is 50%. If mixtures of OCC and ONP are used, the overweight required is a linear weight average of the individual components.

III. The percentage overweight required to maintain tear at a tensile index of 55 Nm/g.

% Substitution		% Overweight	
	ONP	OCC	OCC/ONP
25	50	10	-----
50	100	19	-----
%OCC/%ONP			
15/15	-----	-----	36
25/25	-----	-----	60

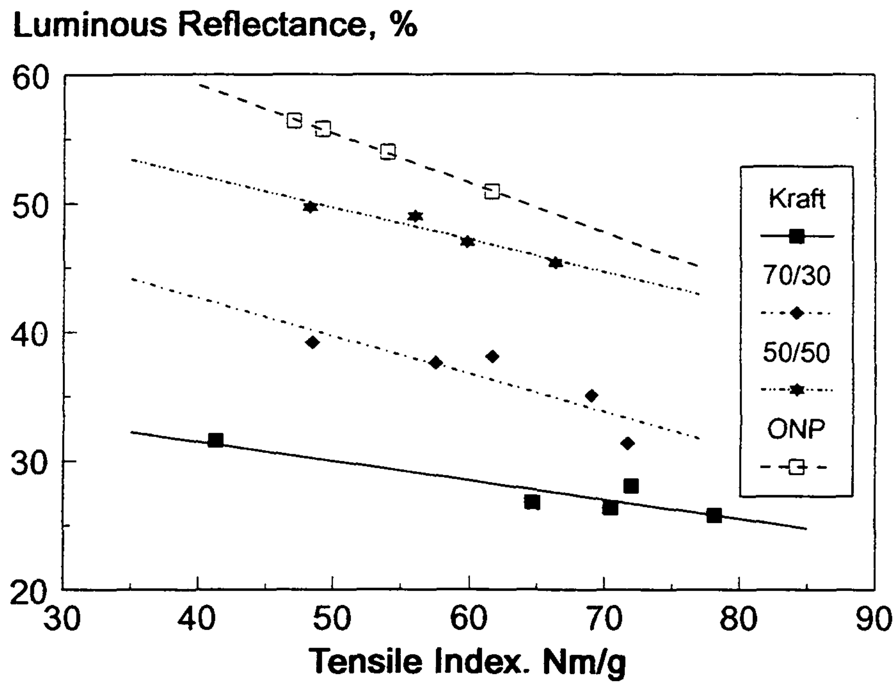
23. The relationship between luminous reflectance and tensile index can be represented by a linear function for kraft and OCC pulps.



Regression information for Figure 23. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	37.7	-.15	85
70% Kraft/30% OCC	36.3	-.145	84
50% Kraft/50% OCC	42	-.254	68
OCC	40.1	-.268	91

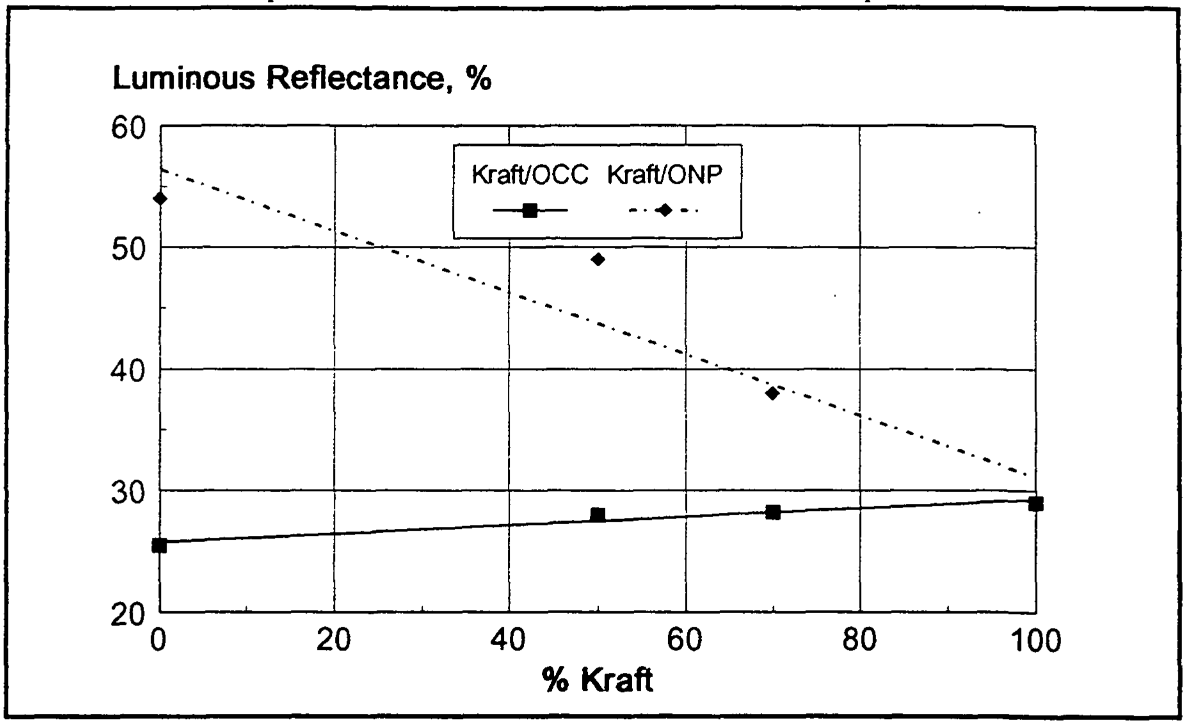
24. The relationship between luminous reflectance and tensile index can be represented by a linear function for kraft and ONP pulps.



Regression information for Figure 24. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	37.5	-.149	85
70% Kraft/30% ONP	54.1	-.294	77
50% Kraft/50% ONP	52.1	-.249	92
ONP	74.9	-.383	99

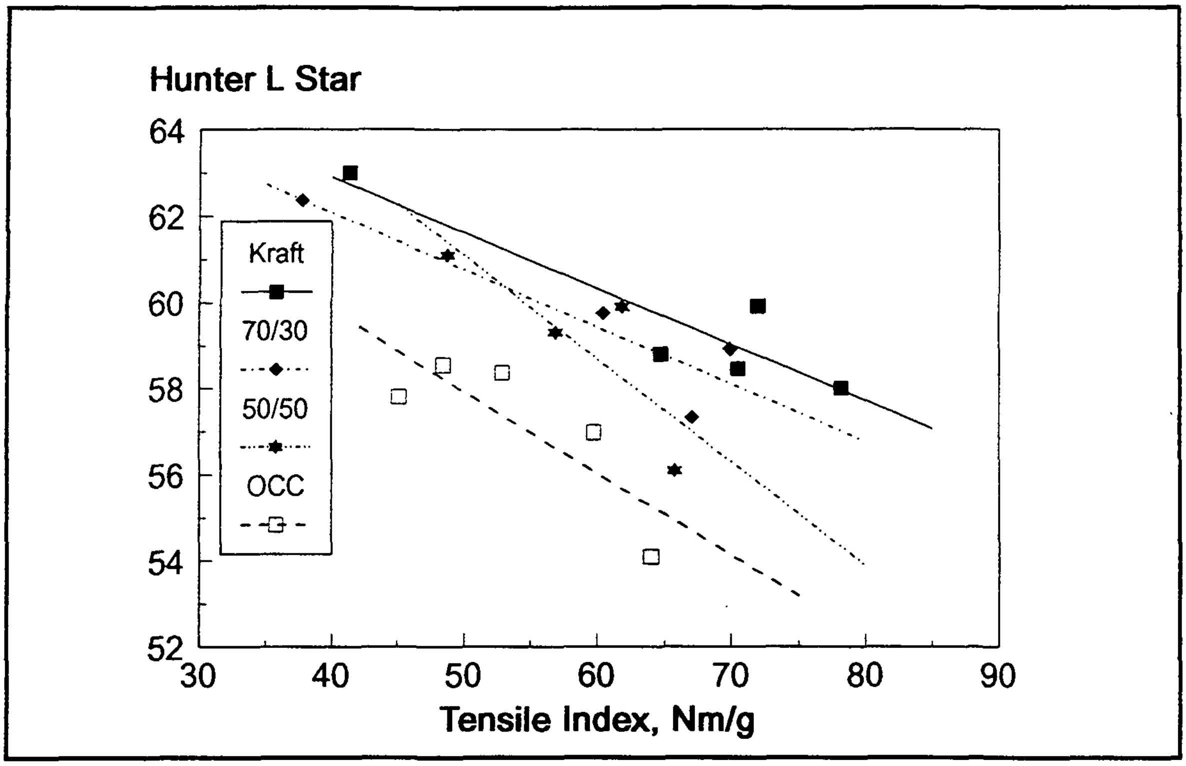
25. The relationship between luminous reflectance and sheet composition is linear.



Regression information for Figure 25. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft/OCC mixtures	56.4	-.253	90
Kraft/ONP mixtures	25.8	.035	95

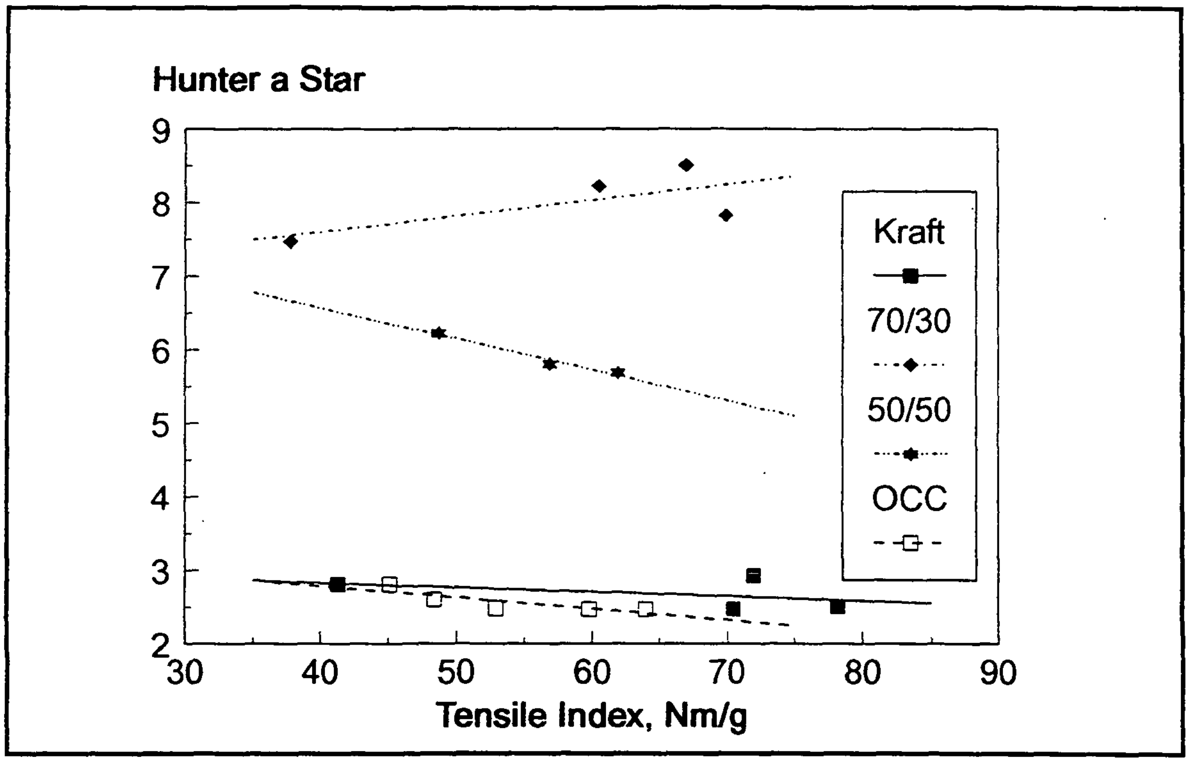
26. Color coordinates for mixtures of kraft and OCC.



Regression information for Figure 26. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	68.1	-.129	85
70% Kraft/30% OCC	67.4	-.133	84
50% Kraft/50% OCC	73.1	-.239	68
OCC	67.4	-.190	67

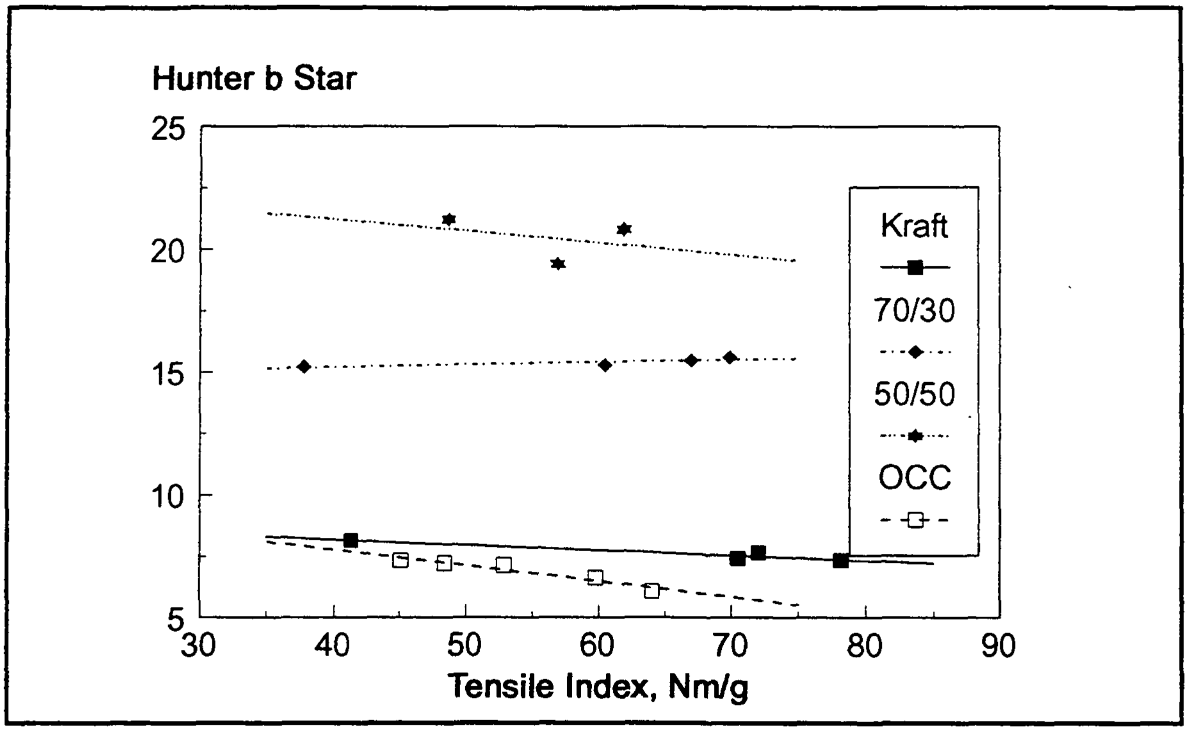
27. Color coordinates for mixtures of kraft and OCC.



Regression information for Figure 27. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	3.08	-.006	21
70% Kraft/30% OCC	6.75	.022	48
50% Kraft/50% OCC	8.25	-.042	97
OCC	3.40	-.015	67

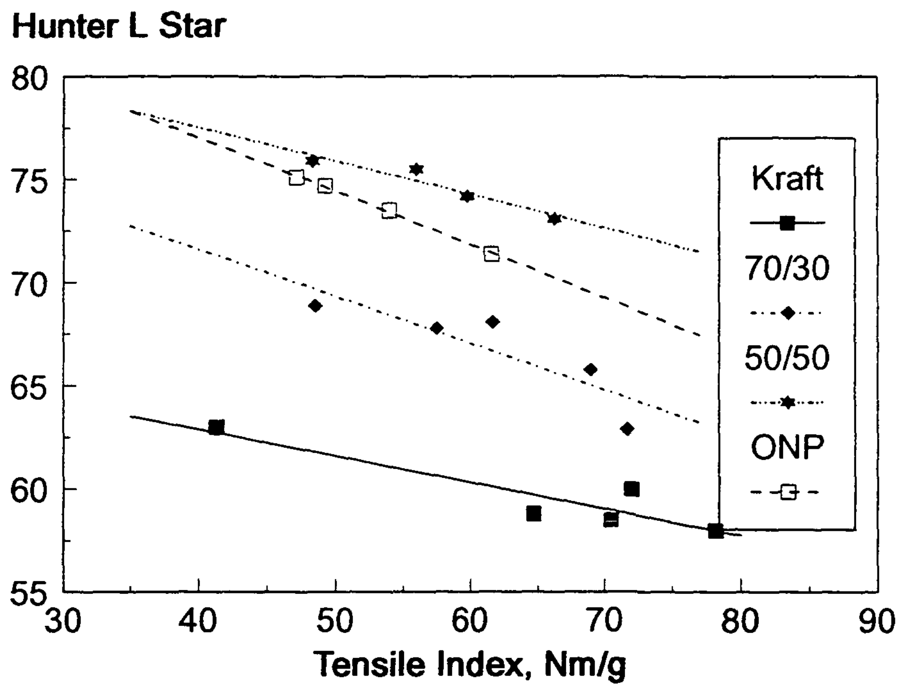
28. Color coordinates for mixtures of kraft and OCC.



Regression information for Figure 28. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	9.05	-.022	91
70% Kraft/30% OCC	14.8	.012	72
50% Kraft/50% OCC	23.2	-.048	12
OCC	10.4	.064	92

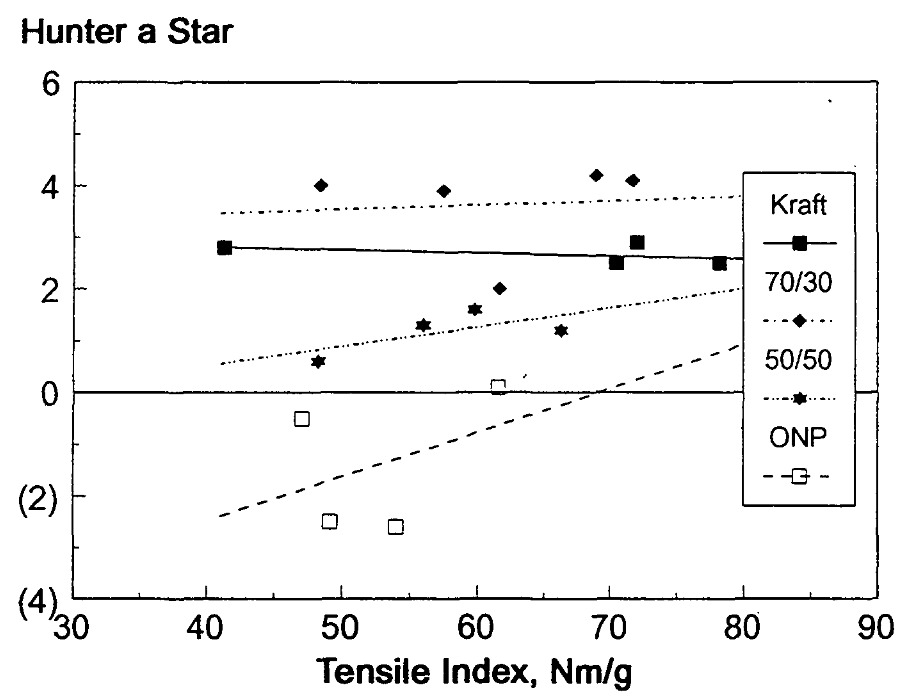
29. Color coordinates for mixtures of kraft and ONP.



Regression information for Figure 29. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	68	-.128	84
70% Kraft/30% ONP	80.7	-.227	76
50% Kraft/50% ONP	84	-.161	91
ONP	87.3	-.257	99

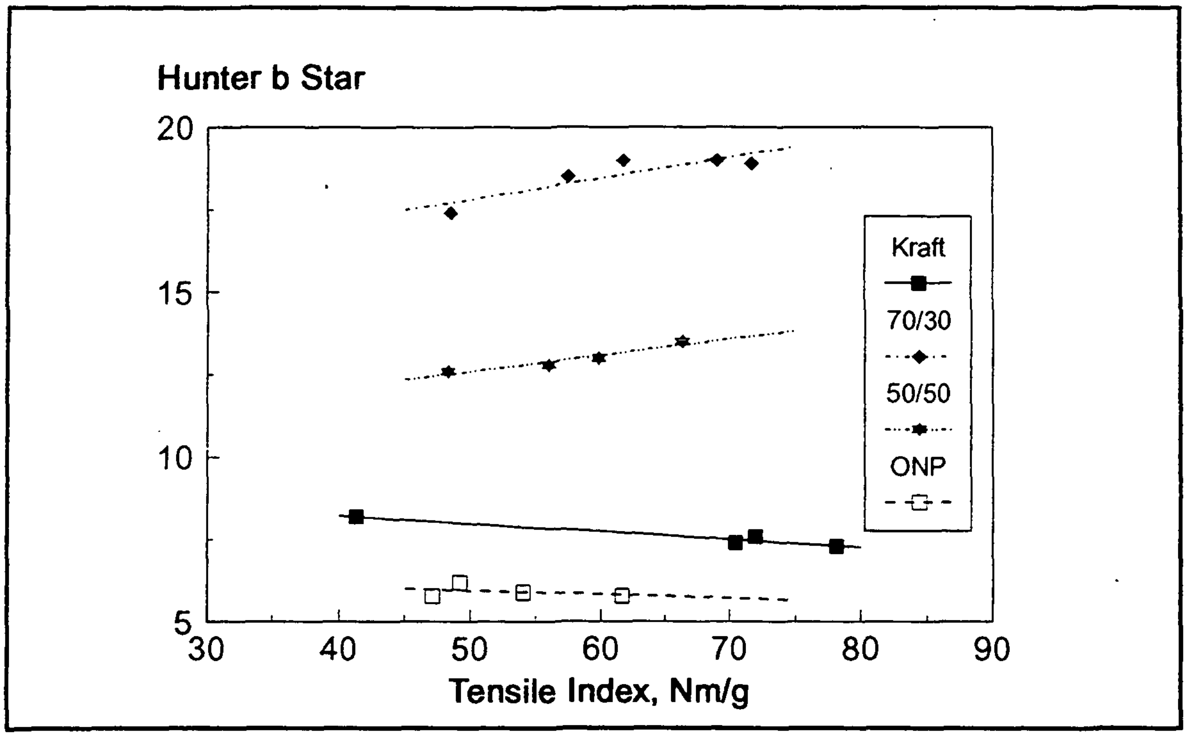
30. Color coordinates for mixtures of kraft and ONP



Regression information for Figure 30. Equation: Y=a+bX.

Pulp	a	b	R^2
Kraft	3.05	-.006	21
70% Kraft/30% ONP	3.13	.001	0
50% Kraft/50% ONP	-.96	.037	44
ONP	-5.88	.005	16

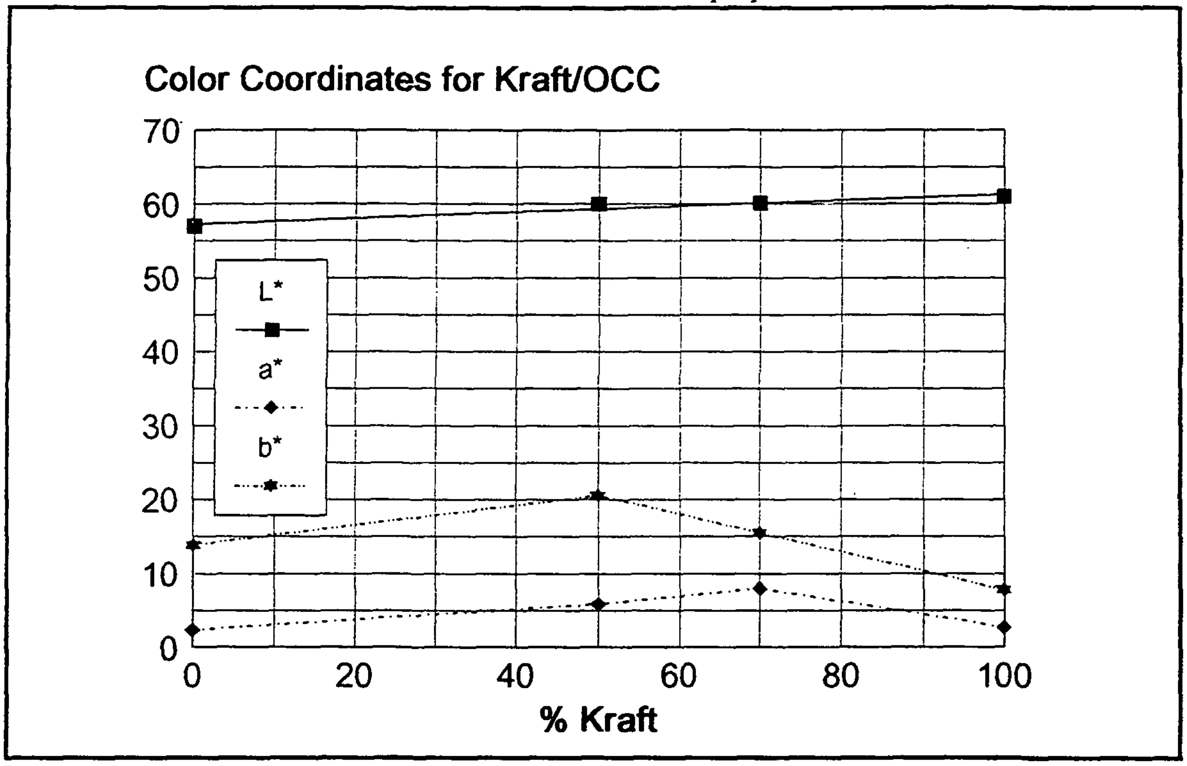
31. Color coordinates for mixtures of kraft and ONP.



Regression Information for Figure 31. Equation: Y=a+bX

Pulp	a	b	R^2
Kraft	9.18	-.024	.94
70% Kraft/30% ONP	14.6	.064	.77
50% Kraft/50% ONP	10.1	.049	.93
ONP	6.53	-.011	.15

32. Color coordinates for mixtures of kraft and OCC pulps.



33. Color coordinates for mixtures of kraft and ONP pulps.

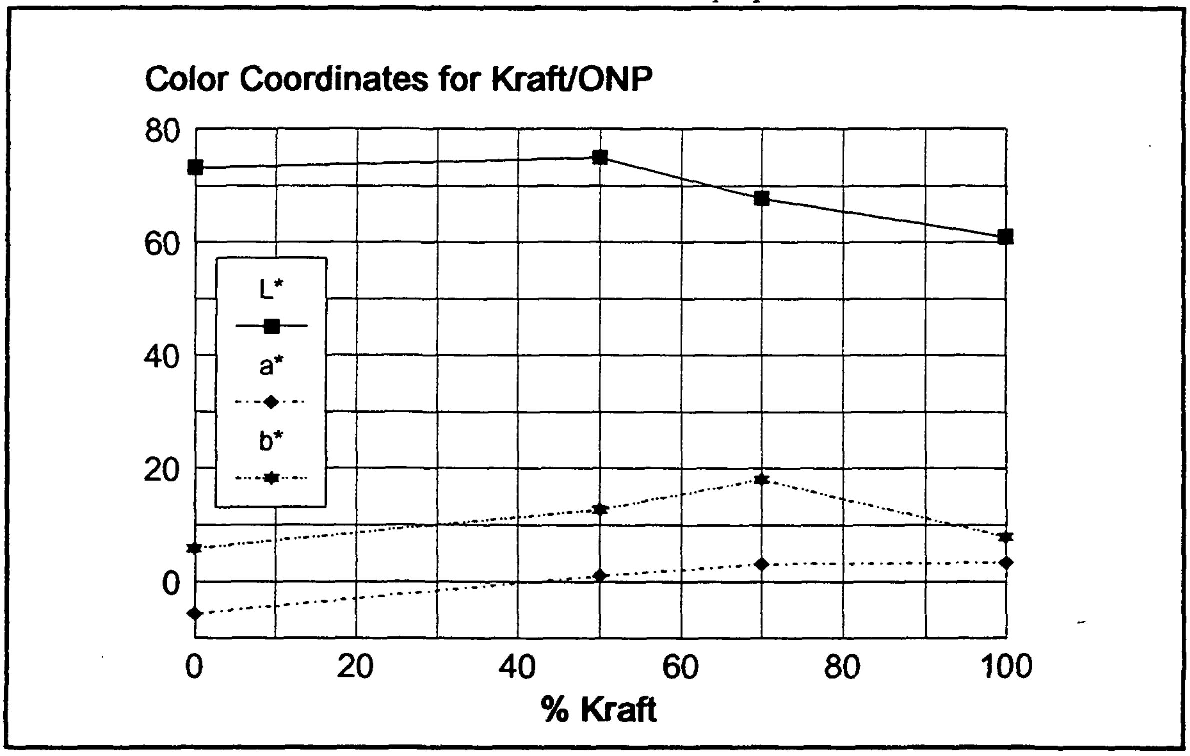


Table IV gives several examples of the overweight required to produce a sheet with satisfactory burst strength after refining to a tensile strength of 55 Nm/g. The picture is the same as the picture for tear. The preferable substitute pulp is OCC. Tensile energy absorption is an important property of multiwall paper. **Table V** gives several examples of the overweight required to maintain this property. Since the amount of overweight required to develop TEA is larger than the amount required for either tear or burst, TEA becomes the controlling variable in deciding how to use recycled fiber in multiwall sheets.

IV. The percentage overweight required to maintain burst at a tensile index of 55 Nm/g.

% Substitution	% Overweight		
	ONP	OCC	OCC/ONP
25	18	6	-----
50	36	12	-----
%OCC/ONP			
15/15	-----	-----	14
25/25	-----	-----	24

V. The percentage overweight required to maintain TEA at a tensile index of 55 Nm/g.

% Substitution	% Overweight		
	ONP	OCC	OCC/ONP
25	36	19	-----
50	48	10	-----
%OCC/ONP			
15/15	-----	-----	29
25/25	-----	-----	28

CONCLUSION

Neither ONP nor OCC is a direct replacement for kraft pulp in multiwall sack grades. These grades can be made to Rule 40 specifications only if the pulp is refined to a tensile index of 55 Nm/g and then overweight is add to overcome the deficiencies in tear. This approach will lead to reduced production when compared to a virgin kraft sheet.

LIST OF FIGURES

SIGNATURES

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Physical Characteristics of Various Pulps

Pulp Description	Freeness (CSF)	Basis Weight (g/m^2)	Density (g/cc)	Moisture Content (%)	Hard Caliper (microns)	Zero Span Tensile Index (Nm/g)	Gurley Porosity (seconds)	Breaking Length (km)	Tensile Index (Nm/g)	Tensile Energy Absorption (J/m^2)	Tear Factor (dm^2)	Tear Index (mN•m^2/g)	Mullen Burst (g cm^2/cm^2)	Burst Index (kPa•m^2/g)	Scattering Coefficient (m^2/kg)	L	a	b	Light Refract (%)
100 % Kraft	204	89.87	0.62	7.78	684.40	142.52	600.00	6.59	64.67	162.30	1.41	13.81	0.68	6.62	16.38	58.78	6.18	20.68	26.80
	327	89.23	0.69	7.30	701.70	159.22	600.00	7.98	78.23	223.20	1.30	12.70	0.70	6.87	16.84	58.00	2.51	7.33	25.80
	467	87.41	0.64	7.59	781.64	164.25	147.00	7.34	71.99	169.10	1.52	14.88	0.61	5.95	19.75	59.96	2.93	7.65	28.10
	618	87.85	0.57	7.35	718.30	153.56	31.60	7.19	70.48	178.60	1.47	14.39	0.63	6.15	18.34	58.45	2.46	7.42	26.43
	800	97.59	0.39	7.51	1143.60	138.84	0.98	4.22	41.38	74.38	2.25	22.08	0.35	3.40	24.01	62.98	2.82	8.16	31.68
100% ONP	25	86.74	0.57	7.91	695.10	107.10	498.72	6.28	61.59	67.23	0.40	3.97	0.31	3.04	36.31	71.36	0.08	5.79	50.91
	50	88.09	0.52	7.91	778.50	113.60	521.68	5.60	53.96	60.30	0.58	5.46	0.29	2.88	41.78	73.49	-2.57	5.86	54.00
	100	85.93	0.46	7.56	865.80	112.20	106.20	4.80	47.07	47.71	0.68	6.68	0.26	2.52	46.87	75.11	-0.48	5.76	56.42
	130	87.10	0.46	7.88	870.30	105.90	66.12	5.01	49.17	64.94	0.73	7.16	0.25	2.48	45.55	74.67	-2.49	6.18	55.75
100% OCC	98	87.16	0.52	7.18	772.90	131.59	600.00	6.53	64.03	145.20	1.13	11.06	0.48	4.69	16.92	54.13	2.48	6.07	22.10
	251	88.80	0.50	7.19	827.20	132.69	365.50	6.10	59.78	137.10	1.22	11.96	0.44	4.32	17.86	56.98	2.48	6.62	24.90
	295	88.95	0.47	7.40	881.10	134.59	127.00	5.39	52.90	102.70	1.29	12.69	0.39	3.86	19.32	58.36	2.49	7.14	26.34
	400	96.25	0.46	7.53	983.70	128.62	44.10	4.94	48.40	106.30	1.56	15.34	0.35	3.47	19.35	58.56	2.61	7.22	26.55
	450	90.05	0.43	7.83	972.50	129.94	24.60	4.69	46.06	85.93	1.69	16.57	0.33	3.27	22.62	57.81	2.82	7.33	27.88
30% ONP - 70% Kraft	175	83.23	0.52	7.65	742.60	157.57	600.00	7.30	71.62	163.10	1.11	10.87	0.56	5.46	18.11	62.86	4.12	18.86	31.42
	307	85.92	0.58	7.80	683.40	147.17	600.00	7.03	68.96	117.00	1.16	11.39	0.57	5.56	24.35	65.82	4.21	18.98	35.10
	436	88.61	0.48	7.84	855.90	145.24	84.32	6.29	61.66	97.82	1.55	15.18	0.46	4.52	30.08	68.07	2.01	19.01	38.07
	560	86.59	0.50	7.60	798.50	143.70	50.13	5.88	57.61	82.81	1.61	15.76	0.46	4.52	30.08	67.76	3.89	18.49	37.62
	800	87.82	0.43	7.87	950.20	141.06	12.26	4.95	48.54	66.94	1.78	17.41	0.35	3.46	31.46	68.89	4.03	17.40	39.19
50% ONP - 50% Kraft	175	87.31	0.50	7.61	801.90	140.97	600.00	6.76	66.27	96.23	0.90	8.83	0.44	4.34	34.35	73.13	1.16	13.46	45.36
	228	89.12	0.47	7.98	874.70	132.84	362.60	6.10	59.86	83.38	1.02	10.03	0.41	4.03	39.02	74.19	1.57	12.96	47.00
	288	88.61	0.44	7.47	908.40	124.38	153.74	5.71	56.00	60.28	1.04	10.23	0.39	3.78	41.75	75.46	1.31	12.78	49.02
	347	86.67	0.40	7.50	1014.70	128.77	46.94	4.93	48.33	50.19	1.26	12.29	0.30	2.97	38.11	75.89	0.59	12.63	49.70
30% OCC - 70% Kraft	223	88.56	0.56	7.53	733.30	159.72	600.00	6.83	66.99	138.20	1.23	12.11	0.58	5.69	15.47	57.33	8.51	16.47	25.26
	379	88.32	0.55	7.52	725.10	148.87	327.90	7.12	69.87	143.10	1.35	13.22	0.54	5.33	18.77	58.91	7.63	15.61	26.94
	515	87.91	0.53	7.47	774.30	147.36	69.91	6.17	60.51	112.60	1.40	13.73	0.53	5.17	19.08	59.75	8.23	15.29	27.85
	700	90.16	0.39	7.46	1082.50	132.11	1.13	3.85	37.78	51.88	2.00	19.57	0.22	2.19	22.36	62.37	7.48	15.22	30.84
50% OCC - 50% Kraft	200	87.58	0.56	8.17	714.00	146.82	600.00	6.70	65.66	141.90	1.23	12.10	0.52	6.06	14.87	58.06	8.51	16.47	23.97
	365	88.72	0.49	7.34	838.40	158.06	437.10	6.79	66.61	104.50	1.26	12.31	0.52	5.10	18.39	59.28	5.81	19.40	27.34
	550	89.82	0.48	7.35	867.10	150.77	78.57	6.31	61.87	110.40	1.52	14.90	0.46	4.50	19.92	59.91	5.69	20.81	28.04
	630	90.92	0.46	7.63	924.50	137.89	3.86	4.97	48.73	98.13	2.03	19.93	0.37	3.64	23.20	61.08	6.23	21.20	29.34
15% ONP/15% OCC/70% Kraft	220	93.39	0.59	7.70	727.70	147.79	600.00	6.81	66.74	139.6	1.12	11.01	0.65	6.4	17.89	59.87	5.68	20.15	27.98
	303	86.62	0.58	7.51	689.50	145.29	417.34	7.08	69.42	134.2	1.23	12.02	0.59	5.81	20.80	61.59	5.63	20.20	29.93
	421	87.12	0.55	7.50	734.70	148.82	173.40	6.59	64.65	116.1	1.39	13.63	0.51	5.01	21.87	62.74	5.70	20.21	31.28
	532	87.47	0.52	7.61	777.80	147.23	50.22	6.27	61.45	107.20	1.54	15.15	0.51	4.96	22.84	63.30	5.24	20.12	31.95
	800	92.76	0.35	8.21	1223.10	145.34	3.03	3.71	36.36	52.37	2.29	22.43	0.29	2.88	27.16	65.46	4.66	19.16	34.65
25% ONP/25% OCC/50% Kraft	164	89.07	0.59	7.61	701.10	148.33	600.00	6.50	63.74	117.50	1.14	11.21	0.53	5.22	21.00	62.84	6.83	13.01	31.40
	280	90.02	0.54	7.79	769.40	129.39	594.59	6.31	61.84	104.10	1.33	13.05	0.46	4.72	23.57	63.81	7.38	12.73	32.58
	370	86.24	0.52	8.02	765.05	147.10	226.77	6.53	64.01	116.10	1.36	13.38	0.49	4.80	25.47	64.65	7.24	12.57	33.88
	458	91.81	0.50	7.65	851.80	146.86	80.44	5.71	55.96	95.56	1.51	14.80	0.46	4.55	24.80	65.79	6.90	12.46	35.02