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THE EFFECT OF MEDIUM PROPERTIES ON THE RETENTION OF CRUSH STRENGTH AFTER CORRUGATING

Project 3747

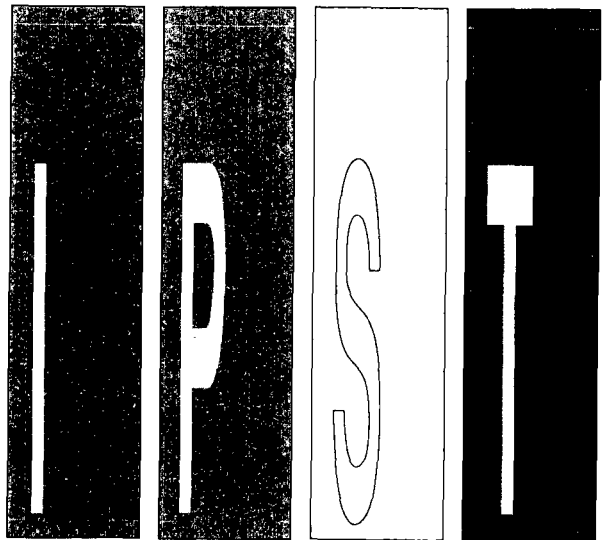
Final Report

CONFIDENTIAL

to the

**CONTAINERBOARD AND KRAFT PAPER GROUP
OF THE AMERICAN FOREST AND PAPER ASSOCIATION**

June 1, 1993



Atlanta, Georgia

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INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

Atlanta, Georgia

THE EFFECT OF MEDIUM PROPERTIES ON THE RETENTION
OF CRUSH STRENGTH AFTER CORRUGATING

Project 3747

Final Report

A Progress Report

to the

CONTAINERBOARD AND KRAFT PAPER GROUP OF THE
AMERICAN FOREST AND PAPER ASSOCIATION

By

G.L. Jones

June 1, 1993

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ABSTRACT

The results of this project confirmed earlier work which found that furnish characteristics have a strong influence on the retention of compressive strength of corrugating mediums during converting. Unlike the previous work which found that OCC showed the highest ratio, the results of this work showed that OCC **lost** the most strength. These differences could be explained by differences in elastic properties of the pre-corrugated sheets. The converting strength ratio, the ratio of fluted edge crush to CD ring crush, increases with increasing elastic modulus of the entering papers and with steam addition. Corrugator speed has a weak positive effect on strength ratio. As the elastic modulus increases, the converting ratio approaches 1.3 to 1.4 which is comparable to the values of 1.6 obtained from the CCT test. This indicates that there is a theoretical upper limit to the strength ratio in the neighborhood of 1.6 to 1.7 which is related to the stabilizing effect of the flute geometry. The converting strength ratio is then reduced from this upper limit through debonding. Strength ratio was reduced from 0.3 to 1.1 under the conditions of this trial. Strength loss is reduced by increasing out-of-plane (ZD) modulus, an effect observed earlier by Whitsitt. This indicates that strength loss is at least partially related to compression of the sheet. Since steam addition is known to decrease modulus which counteracts the effect of higher entering sheet modulus, we can only speculate that the effect of steam is to make the sheet more compliant in the flutes while the entering modulus levels are indicative of sheet toughness. Lubrication had no statistically significant effect on strength ratio. Although sheet hygroexpansivity in the machine direction were statistically significant, values were obtained on only a portion of the handsheet samples and, therefore, these variables were not included in the model.

INTRODUCTION

The fluting process reduces both the MD and CD compressive and tensile strength of corrugating medium resulting in a reduction in both flat crush and combined board ECT. Whitsitt and Sprague (1,2) using short span STFI methods found that MD compressive strength is reduced by 40 % while CD compressive strength is reduced by about 20 %. The short span test permitted the strength to be determined at 9 MD positions over each selected flute from one bonded tip to the next. Strength loss was greatest near the flute tips. Losses were attributed to debonding or delamination between fibers which tends to increase with increasing bending stresses. Bending stresses increase with increasing elastic stiffness of the medium and with increasing strain during fluting. Stiffness would be expected to increase with lower temperature and lower moisture conditions. Stiffness is generally defined as the product of the elastic modulus and sheet thickness. Higher speed is also likely to increase the maximum stresses during fluting. Strains tend to vary mainly as a result of changes in flute geometry and sheet caliper. Thus flute forming losses are expected to depend on factors which influence both the stiffness of the sheets and the strains occurring within the flutes.

Subsequent work (2) focused on methods to minimize strength losses during fluting. Two approaches were evaluated. The first approach attempted to make more effective use of preconditions heat and the second approach used steam to alter the properties of the base medium. Correlation of IPST data from this study showed that retention of compressive strength, RR, is related to the transverse elastic modulus, E_z , the MD elastic modulus, E_x , the basis weight (W), density, ρ , and inversely to the radius of curvature of the fluting rolls, R.

$$RR = 1 - \left(\frac{K}{R}\right)\left(\frac{E_x}{E_z}\right)^{\frac{1}{4}}\frac{W}{\rho} \quad (1)$$

RR is defined as the ratio of the compressive strength after fluting to that before fluting. The compressive strength after fluting was based on the STFI compression test after flattening the flutes.

Both the density and the elastic moduli in the formula depend strongly on bonding. RR is reduced by increasing transverse modulus and by increasing sheet density at a fixed basis weight (i.e. by reducing caliper). Strength losses are also reduced by reduced basis weight. The ratio of the two moduli should be relatively independent of fiber modulus and should depend only on bonding and factors such as fiber orientation and wet stretch (i.e. polar angle).

Densification of the experimental formette handsheets through various pressing levels led to increased specific modulus in each of the sheet directions. Specific modulus, defined as modulus divided by density, is assumed to be a good measure of bonding levels in bonding within the sheet. The transverse modulus was a stronger function of densification than the in-plane moduli. The transverse specific modulus increased by a factor of 3 as sheet density increased by a factor of 2 while the in-plane moduli increased by about 40 % over the same range. This dramatic response of the transverse modulus correlated with increased ECT, flat crush, CD STFI and geometric mean STFI and tensile index.

Air porosity decreased significantly with increasing density. However, this did not necessarily result in reduced bonding, reduced runnability or increased high/lows. Although the results were promising, they did not necessarily show that similar results could be obtained on commercial equipment. These results did not indicate that different furnishes may convert differently although the correlation in Eq.1 indicates that furnishes which result in lower ratios of E_x/E_z should lose less strength during fluting. However, the methods for measuring these moduli and for averaging them over the flutes were not clearly defined. The relationship in Eq. 1 does show that more compressible sheets with lower ZD stiffness should experience greater strength loss. Eq. 1 does not contain a term for the CD modulus which would be expected for a CD mode of failure.

Relationships between the elastic properties of paper are discussed in more detail in APPENDIX A.

A subsequent project on singlefacer green bond strength, 2696-25,(3), identified significant differences between medium furnish types (i.e. green liquor, NSSC, caustic carbonate and OCC) in terms of the observed edge crush versus that predicted from the ring crush or STFI components of the ECT equation. Flat Crush and Concora showed no such furnish influence. OCC had the highest ratio with values near 1.1 while green liquor mediums had the lowest ratio (0.95 to 0.97) with NSSC and Caustic Carbonate in between. The furnish types were compared on the ratio of the observed ECT to the ECT predicted from the combined board equation based on the measured values of either ring crush or STFI as input variables. Because the liner contribution was constant, the observed differences were attributed to differences in the contribution of the mediums. Since the numerator in the ratio was based on the STFI or ring crush before corrugating, the change in ECT in each case was due to fluting losses. This indicated that medium fluting losses were different for different types of furnishes. However, the analytical techniques used were not specific to corrugating medium and it was difficult to determine from the data the causes of the apparent furnish effects.

Analysis of the data base generated during this project indicated that the converting ratio correlated with the elastic properties of the sheet and to the corrugating conditions. However the correlations were not highly significant. The lack of a strong relationship was attributed to the weak dependence of the converting ratio based on ECT on the

elastic properties of the precorrugated sheets.

The goal of project 3747 was to focus specifically on corrugating mediums from each furnish type to determine the fundamental factors which influence strength loss during fluting. The effect of fluting was defined in as the ratio of the fluted edge crush to the CD ring crush or CD STFI compressive strength. The fluted edge crush is an infrequently used Tappi method (T 824 pm-84) in which a test specimen is cut from a fluted medium separated from the liners and crushed in a stiffness and column compression tester designed to conform to the flute design of the corrugated medium. The sample length is 6 inches for both the ring crush and FEC measurement. Thus the ratio of the FEC to CD ring crush measurement should indicate the relative effect of fluting strength loss. The actual test used, a modified version of the standard Tappi method, is described in Appendix B.

The concora crush test or CCT is a related test in which the crush strength is determined on an uncorrugated medium sample held in place in a fluted tester after passing the sample through the concora fluter. Thus CCT includes the effect of the flute geometry in stabilizing the structure thus increasing the compressive strength (4). For 26 lb mediums having average ring crush strength of 40 lb/6 in., typical values of CCT are 60 lb/6 in. Thus the stabilizing effect of the flute geometry is to increase the compressive strength by over 60%. The fluted edge crush test performed on medium after fluting should also include this stabilizing effect as well as the loss due to corrugating. This geometrical effect should be relatively constant and independent of furnish characteristics. However, there is no theoretical or empirical information which predicts this stabilizing effect or the expected interactions between furnish characteristics and the stability imparted by the flute geometry. It is also possible that sheet formation and other factors could interact with the flute geometry.

A similar influence of geometry on the stability of the edge crush strength was seen much earlier in a study of the so-called modified ring crush test method at IPC (1963). In this study sponsored by the CKPG, medium samples tested on 2 inch lengths were on average 23 % higher in compressive strength than samples of 6 in length.

OBJECTIVES

This project was undertaken to (1) confirm furnish differences in converting ratio seen previously, (2) to determine the characteristics which distinguish each furnish and the sensitivity of the converting strength loss to these characteristics and (3) to identify papermaking conditions which would allow for higher converting speeds or reduce the effects of strength losses during fluting at a fixed set of conditions.

SCOPE

Strength after fluting is based on the fluted edge crush test, FEC, described in Appendix B. Initial strength is based on CD ring crush. The ratio of the FEC to the CD ring crush defines the relative strength loss due to fluting. Commercial papers and pulps were obtained from four representative mills. Pulp samples were obtained at approximately the same time the one foot wide roll samples were pulled from the machine. Handsheets would be made over a wide range of densification conditions to generate the large difference in sheet properties. Comparisons of the commercial mediums and handsheets would indicate the influence of commercial practice on converting ratio. Handsheet conditions were limited to refining and pressing levels. Other variables which are known to affect elastic properties and converting such as fiber orientation and restraint during drying were constant.

TEST PLAN

COMMERCIAL MEDIUMS

The test plan called for samples of commercial mediums for each of the four furnish types: green liquor, GL, old corrugated containers, OCC, neutral sulfite semi-chem, NSSC and caustic carbonate, CC from four representative mills. The commercial mediums were not "pure" furnishes but instead contained up to 20 to 30 % OCC.

HANDSHEETS

Pulp samples from each of the pure chemical furnishes and OCC were pulled from the high density chest before blending with OCC and shipped the same day to the Institute where they were washed and stored in separate bags in a refrigerated unit.

Handsheets were made on the Institute Formette Dynamic at the conditions which were intended to produce a range of bonding and density levels. Unlike the commercial mediums, the handsheets were made from each of the "pure" furnishes without attempting to duplicate the commercial blends. It was hoped that using pure furnishes would also help to distinguish the furnish effects more clearly. Sheets were made at three levels of refining and two pressing levels as shown in Table 1. Each sample was refined to the highest freeness level from the "as-received" freeness. The low pressing level was the same as the standard Tappi pressing conditions. Sheets were pressed for five minutes at 50 psi and then for two minutes at 50 psi. For the high pressure condition, sheets pressed at low pressure were pressed a second time at 50 psi for five minutes and 100 psi for five minutes.

The "as-received" freeness of caustic carbonate samples was below 500 ml. Thus, only two freeness levels were used for this furnish.

Table 1. Handsheet Conditions

BEATING CSF	500		350		250	
PRESSING	50	HI	50	HI	50	HI
FURNISH TYPE						
GL	X	X	X	X	X	X
CC	-	-	X	X	X	X
NSSC	X	X	X	X	X	X
OCC	X	X	X	X	X	X

CORRUGATING CONDITIONS

Mediums were spliced together and fluted onto single-faced liners on the Institute corrugator using the C-flute. A light coating of glue was applied along the border of each sheet to hold the single-faced board together during fluting. Each single-faced board was cut along the glue line to remove the liner prior to testing in the fluted edge crush. The corrugated mediums were made at speeds of 500 and 800 feet/minute using combinations of steam and wax bar as shown in Table 2a and 2b. For reasons which are not totally clear, the handsheets did not develop as strong a glue bond as the commercial mediums. As a result, the handsheets steam was required to successfully corrugate the handsheets at 800 fpm. Thus, results are reported only at 500 fpm for the handsheets. W indicates steam and B indicates wax lubrication "Bar". "N" indicates no steam or lubrication. All combinations of speed, steam and lubrication were run on the commercial mediums. This produced a total of $2 \times 3 \times 4$ or 24 conditions. For the Handsheets all combinations were run at 500 fpm and one combination was run at 800 fpm for a total of $1 \times 3 \times 4 + 4 = 16$ conditions.

Details of the corrugator conditions can be found in Appendix B (Preparation of the Unbonded Fluted Medium).

Table 2a. Corrugator Conditions - Commercial Mediums

SPEED FPM	500			300		
WET/BAR	N	W	B	N	W	B
FURNISH	X	X	X	X	X	X
GL	X	X	X	X	X	X
CC	X	X	X	X	X	X
NSSC	X	X	X	X	X	X
OCC	X	X	X	X	X	X

Table 2b. Corrugator Conditions - Handsheets

SPEED FPM	500			300		
WET/BAR	N	W	B	N	W	B
FURNISH	X	X	X	-	X	-
GL	X	X	X	-	X	-
CC	X	X	X	-	X	-
NSSC	X	X	X	-	X	-
OCC	X	X	X	-	X	-

FLUTED EDGE CRUSH TEST

The fluted edge crush was determined using a modified version of Tappi standard test T 824 PM 83 using a modified test jig with the 'C' flute designed especially for this work. The jig is available for testing through the Research Services division of the Institute. A test procedure can be found in Appendix B. In the Tappi Standard edge crush test, samples are pre-cut, run through the Concora to produce an A flute and then tested in the test jig. In the modified test, the sample is corrugated first and a large piece is cut and placed in the test jig. The sample is cut with a sharp razor to the correct width while being held in a specially-supported fluted rack, removed and tested in the stiffness holder where the compression load was applied to the edges of the flutes.

PHYSICAL PROPERTY TESTING

Test flow plans for the handsheets and machine papers are shown in Figures 1 and 2, respectively. Handsheets were made with 10 to 20 replicates at each condition. A portion of each set was then corrugated and tested for FEC and the remaining samples were tested for ultrasonic elastic modulus, tensile strength, and hygroexpansivity. Handsheets are made at a total of 24 papermaking conditions. Sufficient replicates were made at each condition to provide samples for the corrugating runs and to test separately for compressive strength, elastic and other properties. Sample sizes were sufficient to perform at least 10 replications; tests were made for all measurements.

Handsheets and machine papers were tested for properties shown in Table 3.

Table 3. Physical Property Data

Physical Property Data
Basis weight
Density
Caliper
Moisture
Tensile Strength
Stretch at Break
In plane Elastic Moduli
Out of Plane Moduli (ZD)
Hygroexpansivity at Two Relative Humidities <ul style="list-style-type: none"> - Machine Direction - Cross Direction
Ring Crush MD and CD
STFI Crush MD and CD
Fluted Edge Crush

DATA BASE

DATA COVERAGE

Properties shown in Table 3 were not generated for all test conditions. Most critical data such as the elastic properties, ring crush and fluted edge crush were determined on essentially all 222 samples. This made it possible to model the converting strength ratio in terms of the elastic properties. Hydroexpansivity was determined only on a subset of the samples. Since hydroexpansivity was found to be significant in predicting compressive strength retention, this limited the development of the most general model. STFI and tensile strength were obtained on a subset of the samples. In addition, the lack of data coverage at 800 fpm for the handsheets limited the range of the effect of corrugating conditions in the model. The implications of the data coverage are discussed in following sections on Data Modeling.

DATA SUMMARY

The data are summarized in Appendix C. Each sample was assigned an observation number by SAS (Statistical Analysis System) which was used to tabulate, graph and analyze the data and to develop the correlation models which are described later.

The complete set of experimental data can be found in Appendix C. The data are grouped into two main categories by forming method, i.e. handsheets and machine papers. Handsheets make up 174 observations or data points and machine papers make up the remaining 48 observations, 174 through 222. Samples 210 through 216, which were green liquor handsheets, lacked ultrasonic modulus values and were not used in developing the model.

The data are grouped by pulp source, i.e. pulp type, as follows:

Pulp Type: cc = caustic carbonate, nssc = neutral sulfide semi chemical,
gl = green liquor and occ = old container cartons

Handsheet forming conditions, CS freeness and pressure

Corrugating Conditions: Speed, Presteam, Lubrication (Wax)

Properties: basis weight, caliper (mils), Density

Hydroexpansivity:

MD from 47.7 to 75.5 relative humidity

MD from 75.5 to 93.4 relative humidity

CD from 47.7 to 75.5 relative humidity

CD from 75.5 to 93.4 relative humidity

Elastic properties

MD, CD, ZD moduli, in-plane shear modulus, Poisson Ratio

Compressive strength: MD, CD Ring Crush, MD CD STFI,
Fluted Edge Crush

Ratio of FEC to CD ring crush

Predicted Ratio from Model 1

Ratio of FEC to CD STFI

Tensile Strength, MD and CD

TEA, MD and CD

DATA ANALYSIS

The data were analyzed with several objectives in mind:

1. To confirm results of previous projects which found that converting ratio differed significantly between furnish types.
2. To develop a model or models between converting ratio and converting conditions and furnish characteristics.
3. To improve understanding of the sensitivity of converting strength loss to converting conditions and furnish characteristics.
4. To determine ways to improve converting efficiency through changes in papermaking conditions.
5. To determine ways to retain strength at higher converting speeds.

The data were analyzed using SAS which includes a wide variety of built-in routines (procedures) to perform analysis of variance and linear or nonlinear regression of the data.

EFFECTS OF FURNISH TYPE ON COMPRESSIVE STRENGTH

Both CD and MD ring crush differed significantly for the four furnish types as shown in Figures 3 and 4. For the machine papers containing mainly chemical furnishes, the MD and CD ring crush averaged approximately 52 and 40 lb/6 in. respectively while the values for the OCC papers averaged 41 and 32 lb/6 in. The ring crush for the handsheets showed variations between all furnishes with the largest values seen with the caustic carbonate followed by the green liquor, NSSC and then the OCC. Thus the trends were qualitatively similar for the handsheets and the machine papers. The average ring crush values for the OCC handsheets were 50 and 38. The differences were judged to be significant because they were larger than the standard deviation of the ring crush measurement.

EFFECT OF FURNISH ON FLUTED EDGE CRUSH -AVERAGE OVER CONVERTING CONDITIONS

The fluted edge crush also differed significantly between the furnish types. For the machine papers, the average FEC for all corrugating conditions (Fig. 5) showed that OCC had the lowest FEC (average of 31) and the other three furnishes had similar strength values ranging from 40 to 46 lb/6 in. The handsheets showed a similar trend with the caustic carbonate and green liquor showing the highest FEC values (46 and 47) and the NSSC and the OCC showing significantly lower FEC (36 and 38) (Fig. 6). The levels are the average over all corrugating conditions. The highest FEC values were obtained with caustic carbonate handsheets (average of 50 lb/6 in.), while the lowest values were found for the OCC commercial papers (average of 32 lb/6 in.).

EFFECT OF FURNISH AND CONVERTING CONDITIONS ON FLUTED EDGE CRUSH

Figures 7 and 8 show the effects of speed, steam and wax for each of the furnish types for handsheets and machine papers respectively. The levels are rank ordered from left to right. Each bar represents a corrugating condition (speed, steam or lubrication). The first set of number indicates corrugating speed. The second set of symbols represents steam application (steam or no steam) and the third set represents lubrication (wax or no wax). Inspection indicates that steam addition has a positive effect for both handsheets and machine papers while wax tends to have little effect or a negative effect. Speed in some cases has a positive effect for the handsheets, while it generally has a negative effect for the machine papers.

The only unusual samples are the caustic carbonate and NSSC machine papers. With these the highest fluted edge crush was obtained with no steam and with lubrication. This suggests that there are subtle effects of surface friction, speed and furnish variables which cannot be easily detected with current methods.

EFFECT OF FURNISH AND CORRUGATING CONDITIONS ON CONVERTING STRENGTH RATIO

The ratio of CD ring crush to FEC is summarized in a series of figures in which the results are broken down to include more corrugating conditions. Figures 9 and 10 show the ratio after averaging over all corrugating conditions for handsheets and machine papers, respectively. In Figures 9,11, and 12 the horizontal lines through each bar are not significant. For the machine papers, the OCC and Caustic carbonate strength retention ratio was approximately 1 while the ratios for green liquor and NSSC are higher, 1.2 and 1.15. This indicates that the GL and NSSC retained a larger percentage of their original strength during corrugating than the OCC and Caustic Carbonate furnishes. Trends for the handsheets shown in Figure 9 are essentially the same for the OCC and caustic carbonate while the NSSC lost more strength during converting (ratio of 0.88) and the green liquor lost less (ratio of 1.01).

Overall, there was less variation between furnishes for the handsheets than the machine papers and the converting ratios were somewhat lower indicating that the handsheets lost more strength during converting than the machine papers. Since the handsheets were not run at the higher corrugator speed (800 gpm), overall they performed more poorly than the machine papers. The smaller variation between the furnish types for the handsheets is somewhat surprising considering the deliberate attempt to form handsheets with a wide range of properties and the larger variation in ring crush.

The effects of presteaming and pulp type on converting ratios are shown in Figures 11 and 12. Generally steam has a beneficial effect. The ratio increases up to 10 % with the addition of steam. The effect of steam appears to be somewhat larger for the handsheets (Fig. 11) than for the machine papers (Fig. 12). The average handsheet converting ratios with steam approach those for the machine papers without steam.

Figures 13 and 14 show the effects of speed, steam and lubrication (wax) on the converting ratio for handsheets and machine papers respectively. The ratios are sorted and displayed in increasing order for each furnish type. In general the highest ratios are obtained at the lower speed and with steam addition while the effect of lubrication is mixed. The effects are not the same for each furnish and are therefore difficult to generalize. The effects of corrugating conditions for all types of furnishes and papers are summarized and discussed in more detail in the following sections. As with the FEC, the two exceptions to the effect of steam on converting ratio are seen with the CC and NSSC machine papers. This is expected, of course, since the ring crush values are the same and simply normalize each set of values while having no effect on the influence of corrugating conditions.

EFFECT OF ELASTIC PROPERTIES ON CONVERTING RATIO

Previous work by CKPG and fundamental studies have shown that elastic properties play an important role in both compressive strength as well as strength after converting. Therefore, one of the objectives of this project was to determine if the furnish effects seen previously could be related to differences in elastic properties of the pre-converted mediums. In general the results confirmed previous work which showed a significant effect of elastic properties, measured ultrasonically at IPST, on both compressive strength and converting ratio.

CD Modulus

The effect of CD modulus on converting ratio for all samples is shown in Figure 15. The trend plot shows that converting ratio tends to increase as the CD or cross direction modulus of the entering sheet increases. The results are grouped by combinations of pulp type and paper type (handsheet and machine paper). Values for the OCC machine paper data were not included in the plots. The variations shown include all handsheet and corrugating conditions. The trend is for the ratio to spread out or show a larger

variation at increasing levels of CD modulus. The machine paper data tend to fall within the range of the handsheet data indicating that these are not separate categories. CD modulus was shown to be a significant factor in ring crush.

Figures 16 through 19 show effect of CD modulus on converting ratio for each pulp type. The effect is quite strong for NSSC and green liquor and somewhat weaker for OCC and caustic carbonate. The variation in CD modulus for the NSSC and green liquor is also larger than seen for the OCC and caustic carbonate. A regression line and 95% confidence limits are shown for each plot. Variations in converting ratio at each level of CD modulus are due to converting conditions.

CD Specific Modulus

The effect of CD specific modulus, defined as the CD elastic modulus divided by the sheet density, on converting ratio is shown in Figure 20. As with the modulus, the effect is approximately linear and increasing with increasing specific modulus. The specific modulus is thought to be a good measure of bonding levels in the sheet. By dividing out the effect of sheet density, the specific modulus has units of velocity squared and is thought to be related to the fiber modulus or to the bonding level in the sheet. The range is significant with the NSSC handsheets having the lowest CD specific modulus values and the caustic carbonate handsheets having the highest values.

ZD Modulus

The effect of ZD or out-of-plane elastic modulus on converting ratio is similar as shown in Figure 21. The OCC data are not shown. The trends show that the converting ratio increases with increasing ZD modulus although a maximum in the plot may occur at 0.15 GPa. Out-of-plane modulus is a measure of compressibility and compressive stiffness. A higher ZD modulus indicates a lower compressibility. Previous work has shown that strength losses are reduced as the sheet becomes progressively less compressible. Figure 22 shows the variation in ZD modulus for the NSSC furnish. The trend is quite strong, however, the trends for the other furnishes are not as obvious or the data coverage is quite sparse.

Shear Modulus

The effect of in-plane shear modulus shown in Figure 23 indicates that the effect of shear modulus is weaker than that of in-plane CD tensile modulus although it is significant and the effect tends to level out at higher shear stiffness levels. Converting and fluting operations generate stresses in both compression, tension and shear. These in turn induce strains in the sheet which may rupture bonds leading to a reduction in elastic stiffness and a reduced ability to withstand edgewise compression.

Figures 24 through 27 show the effect of shear modulus for each furnish. Again, the

NSSC and green liquor have similar values and ranges and the trends are stronger, while the ranges for the caustic carbonate and OCC are smaller and the trends weaker. The OCC shows the smallest range but a much larger sensitivity than the caustic carbonate. All but the green liquor furnish show a maximum of around 1.2 or 1.3 GPa for all furnishes. This indicates that the model should include a quadratic in this variable.

EFFECTS OF REFINING (BEATING) AND PRESSING ON HANDSHEET PROPERTIES

Density

The effects of refining and pressing on handsheet density for the four furnish types are shown in Figure 28. The OCC produced the highest density sheets for all levels of refining and pressing. The other furnishes fell into a similar range of density values. As expected, the highest density sheets were obtained at the highest pressure and highest refining level (lowest freeness). Freeness values ranged from 500 to 250 ml. Densities ranged from a low of about 0.33 g/cc for the NSSC at the low or high pressure and high freeness to 0.572 for the OCC at 250 ml and 100 psi pressure.

Since it is well known that densification is a strong indicator of bonding and therefore strength and elastic stiffness, the experimental conditions were successful in generating handsheets with a significant range in density and bonding levels.

Tensile Strength

The effects of refining and pressing on handsheet tensile strength are shown in Figure 29. The effects are similar in that the OCC handsheets have the highest tensile strength and the other furnish types are grouped together. The highest strength is consistent with the highest density.

CD Modulus

Figure 30 shows the same trends for the CD elastic modulus. Again, the OCC achieved the highest CD modulus values, and the highest modulus was obtained at the highest refining level and highest pressure. There was more differentiation between the furnishes at the highest bonding conditions with the caustic carbonate followed by the green liquor and then the NSSC.

ZD Modulus

The effects of refining and pressing on ZD modulus for three furnishes are shown in Figure 31. Refining and pressing increase ZD modulus in most cases. The pattern is essentially consistent with the densification of the sheet. However, at the lowest freeness, pressing may have less effect on ZD modulus than at lowest refining levels.

EFFECTS OF HYGROEXPANSIVITY

Although hygroexpansivity was found to play a significant role in converting efficiency, scatter plots of the data did not show any apparent trend. The effects are probably obscured by those of the other variables and the apparent correlation between hygroexpansivity and elastic properties.

OTHER PAPERMAKING FACTORS

Other papermaking factors which play a role are formation and orientation angle. Neither of these variables were deliberately varied in the experiments. The orientation angle is made up of two components related to average fiber orientation and built-in stresses in the sheet. These then account for the orientation ellipse. Formation and orientation were not evaluated in this project. However, improved formation in the machine papers could have accounted for the generally higher performance compared to the handsheets. The MD/CD tensile and elastic ratios in the machine papers and handsheets indicated that the fiber orientation and built-in stresses were relatively uniform between samples.

The maximum and minimum converting ratios found in the data base were formed under conditions shown in Table 4.

Table 4. Maximum and Minimum Converting Ratios Observed

Property	Maximum	Minimum
Converting Ratio	1.33	0.55
Density	0.696	0.399
MD Modulus GPA	6.4	3.39
CD Modulus GPA	2.87	0.96
ZD Modulus	0.151	0.052
Shear Modulus	1.64	0.62
Poisson Ratio	0.33	0.49
Fluted Edge Crush	50.51	16.3
CD Ring Crush	37.9	29.3
CD STFI	14.61	
Converting Speed	500	500
Steam	yes	no steam
Lubrication	no	wax applied

Judging by the overall range of the data, these two points indicate qualitatively that higher moduli tend to reduce strength loss in fluting. Higher entering moduli also lead to higher ring crush. Steam also reduces converting losses and lubrication has little effect or possibly a negative effect.

CROSS CORRELATIONS BETWEEN VARIABLES

Cross correlation of the data and other information are shown in Appendix D. Cross correlations were determined on variables which had a significant influence on converting ratio. These were inverse of the MD, CD and ZD elastic moduli; inverse of MD specific modulus; inverse in-plane shear modulus and in-plane Poisson ratio and the four hygroexpansivities; two in the machine direction at medium to high relative humidities, HYGMDM and HYGMDH; and two in the cross-direction at medium to high relative humidities, HYGCDM, HYGCDH. The modulus variables were replaced by the inverse when the trends showed that the effect of modulus tends to diminish at higher values. The model fit was improved by using the inverse of each of the modulus variables.

A cross correlation analysis was performed on the variables in the model to determine the degree of independence or interdependence of the variables in the model. It is obvious that some variables such as corrugator speed and steam usage are truly independent. However, most other variables such as sheet density and elastic properties depend on furnish and papermaking conditions. For the handsheet samples it would have been possible to reduce the set of variables to include CS freeness and pressure. However, this simplification could not be used for the machine papers. Since one of the goals was to develop a model on the combined machine paper and handsheet data, it was not possible to add fundamental variables such as pressure and CSF to the model.

It was judged not to be particularly useful to develop models for sheet density and modulus in terms of CSF and pressure because the furnish effects also appeared to be very significant. In particular, the data showed that the OCC handsheets developed significantly higher density and elastic modulus than the other furnish types.

The cross correlation analysis showed significant correlations between in-plane inverse moduli ($IE_X = 1/E_X$ and $IE_Y = 1/E_Y$). This is expected, due to the relatively reproducible fiber orientation angle in the sheets. The highest correlation between the MD inverse modulus was with the inverse in-plane shear modulus (0.88). The lowest, with the exception of the CD expansivities, was with the inverse MD specific modulus. This rather surprising result is probably due to the factor for density in the specific modulus. Out-of-plane modulus ($1/E_Z = IE_Z$) also correlated with in-plane moduli. This is also expected based on modeling of other ultrasonic modulus data. The highest correlation was with the inverse specific modulus ($\rho/E_X = IR1$). This is also probably due to the strong dependent of ZD modulus on sheet density. The in-plane Poisson ratio ($G21$) correlated most strongly with the inverse CD modulus (IE_Y) (0.612). MD hygroexpansivities correlated most strongly (0.32) with MD modulus. CD hygroexpansivities correlated

negatively with ZD modulus (-0.37).

The results of the cross-correlation analysis can be found in Appendix D. For each variable pair, the correlation coefficient is shown as the first number in the matrix. The second is the probability that the correlation is significant (a low number indicates a high correlation) and the third is the number of observations (data points) available for this correlation. The values along the diagonal represent the auto-correlation and are therefore one for each variable. The off-diagonal values give the correlation between different variables in the data base. Only the "independent" variables considered in the model were correlated by this method.

CONVERTING RATIO MODEL

A regression model was developed for the converting ratio in terms of independent or nearly independent variables. Regression of the data quickly showed that the furnish type was significant. However, the furnish type does not provide much information on the characteristics which may influence converting strength. It also can lead to the misleading impression that one type of furnish loses less strength than another when the reverse may occur in another situation. It was possible to predict the converting efficiency (ratio) using the elastic properties rather than using the furnish type without a significant loss in accuracy. Converting conditions such as speed and steam addition are also expected to be important. The effects of these conditions should be interactive with the elastic properties.

Model development employed a multi-step procedure beginning with scatter plots of converting ratio against process variables or elastic properties. Stepwise regression was used to select the most important variables. Various combinations of the variables were entered into the selection process including linear terms, product terms and squared terms. However, it was not possible for the system to test all possible forms or combinations of the variables. A first principles model was not available to provide any guidance in selecting the forms of the variables. After selecting the "best forms" of the variables and the minimum set of variables, model coefficients were determined by standard regression techniques using SAS (Statistical Analysis System.)

The model was developed in terms of the inverse of the elastic constants, an interaction between corrugator speed and shear modulus and an interaction between inverse modulus and steam. Neither steam alone nor speed alone were significant. Interactions between speed and steam and sheet elastic properties are expected based on intuition and first principles. The inverse terms were used because the converting ratio appears to approach an upper limit as the elastic stiffness or modulus increases. The intercept in the model was 1.35. The maximum converting ratio seen in the data was 1.33 for a machine paper from a green liquor furnish. Higher ratios are possible for the modified crush test when the sample is deformed in the concora tester, which results in very little delamination.

The regression equation is given by,

$$CVR = 1.35 - \frac{0.385}{E_x} - \left(\frac{0.220 + 0.365\rho + c \text{ steam}}{E_y} \right) - \frac{6.0 \times 10^{-3}}{E_z} + 3.7 \times 10^{-4} v_{12} \text{ SPEED} \quad (2)$$

where CVR is the converting ratio defined as the ratio of FEC to CD ring crush (dimensionless).

E_x - machine direction ultrasonic modulus, units of GPa (pressure)

E_y - cross direction ultrasonic modulus, units of GPa (pressure)

E_z - out-of-plane ultrasonic modulus, units of GPa (pressure)

ρ - density

v_{12} - in-plane Poisson Ratio

SPEED - corrugator speed fpm

C has a value of 0.1065 when steam is not used, and 0 when steam is used. Thus, steam addition improves converting ratio and increases fluted edge crush. The effect of wax is negligible on the average. The Poisson ratio is the ratio of strain induced in the sheet in one direction by a strain in a perpendicular direction.

All these variables are generated from just two ultrasonic tests—one for in-plane ultrasound elastic properties and the second for out-of-plane ultrasound properties. Both tests require the basis weight of the sheet. Caliper and density are also determined through the test procedure.

MODEL STATISTICS

The model statistics are summarized in Appendix E. It also contains a listing of the 203 sample values, the data values and the residuals. Only 203 of the 222 samples could be used because about 20 samples were missing one or more elastic property value. Variable T1 is the name given to the ratio of FEC to ring crush in the correlation procedure. A scatter plot of the predicted against measured values is shown in Figure 20. The machine paper data and handsheet data fall on the same line. The range in the model predictions is smaller than the data indicating that not all the observed variability can be measured or explained by the experimental variables. The 95% confidence limits are shown around the regression line through the data.

Hygroexpansivity in the MD direction at the medium and high relative humidity ranges

was found to be significant. However, since hygroexpansivity was available on Lyon 103 samples, any model containing these terms would have been based on fewer samples. Also the addition of these terms changed the signs of the other terms in the model making it difficult to interpret the effects of the elastic properties. One reason for this was the partial correlation between hygroexpansivity and the elastic properties. This also made it difficult to recommend conditions which would reduce strength loss.

Terms were dropped from consideration when the F Value was less than one. For model one the terms in descending order of importance (based on Type 1 sum of squares):

1. Inverse of the CD modulus
2. Inverse of the MD modulus
3. Interaction between steam and inverse CD modulus
4. Inverse of ZD modulus
5. Interactions between in-plane Poisson ratio and speed
6. Inverse of CD specific modulus (or density times inverse CD modulus)

The relative importance of the variables is proportional to the sum of squares contributions. The first two elastic terms contribute 2 out of a total of 2.4 for the model indicating that the first two terms are five times more important than all the other terms.

Interactions between MD and CD modulus and other elastic variables make it difficult to define a set of truly independent variables. A more comprehensive set of independent variables would probably include the following: polar angle, fiber orientation, machine restraint or stretch, fiber modulus, pressing pressure(s), CS freeness or refining loads.

The overall fit to the data is 0.630 or about 2/3 of the variation of the data. Earlier analysis of the data, which included only 88 samples gave a similar picture, but a higher level of fit to the data ($R\text{-squared} = 0.88$).

The model has replaced furnish types with ultrasonic properties. However, the process conditions which influence these ultrasonic properties are only partially understood. For example, it is well known that increasing density tends to increase in-plane modulus and generally to increase out-of-plane modulus. But, it is not clear in general whether shear modulus or Poisson ratio is changed. Shear modulus should be related directly to bonded area or specific bond strength. Density is increased by refining and pressing as shown in this study. Other influences include species characteristics which influence fiber flexibility. Fiber flexibility influences both densification as well as bending stiffness.

Other influences on elastic properties include fiber orientation and machine restraint. The higher the CD orientation, the higher the CD modulus. This will influence not only MD/CD tensile and elastic ratios but also ZD modulus and possibly shear modulus.

IMPLICATIONS OF THE CONVERTING MODEL

Converting losses are reduced by increasing both the in-plane and out-of-plane (ZD) modulus of the sheet. This can be done in various ways, but the most common practice is to increase the density of the sheet. Stiffer fibers may also translate into a higher modulus sheet. However, stiffer fibers may also bond more poorly and result in a lower modulus rather than a higher modulus. However results reported to the CKPA by Sprague and Whitsitt (5) show that increasing fiber modulus increased compressive strength and sheet modulus. At the same density edgewise compressive strength was increased linearly by changing fiber modulus through substitution of virgin pine, douglas fir, loblolly pine, and gum. Therefore, fiber species can influence modulus through the fiber modulus and it appears that density can be controlled as a separate variable.

Steam addition also reduces the loss and increases the ratio. Speed has a slightly positive effect, but the contribution is not large. Although the effect of speed is not large, it does not always reduce strength.

Another means of influencing the elastic constants and compressive strength is through manipulation of the MD/CD ratio through polar angle, fiber orientation and machine direction stretch or restraint. Because the CD modulus is lower than the MD modulus, the term involving the inverse CD modulus is generally larger than the term containing the MD modulus.

The first two terms in the model can be rewritten by substituting the MD/CD ratio and factoring out the CD modulus

$$\begin{aligned}
 CVR = 1.35 - \frac{1}{E_y} & \left(\frac{0.385}{MD/CD} - 0.220 + 0.365\rho + c_{steam} \right) \\
 & - \frac{6.0 \times 10^{-3}}{E_z} + 3.7 \times 10^{-4} v_{12} SPEED
 \end{aligned} \tag{3}$$

As the MD/CD ratio increases and the sheet becomes more oriented in the machine direction, the term inside the brackets decreases and the strength loss is predicted to decrease. The addition of steam drops the terms inside the brackets by 0.106. The effect of steam is reduced as the modulus increases. Density enters directly in the numerator and indicates that as density increases the loss terms also increases. However, the modulus terms are strongly density-dependent and tend to increase faster than linearly with density. Thus the net effect of density is probably to decrease converting loss.

ZD modulus is a measure of the inverse of the compressibility of the sheet. Thus the inverse modulus is a measure of its compressibility. As the compressibility decreases, the strength loss also decreases. This behavior agrees with Whitsitt's observation described previously. However, Whitsitt found that MD modulus increased fluting loss while our data show that increasing MD modulus also tends to decrease strength loss.

CONCLUSIONS

One interpretation of the results is that strength loss during fluting is reduced by increasing the toughness of the entering sheet. Sheet toughness is related to bonding and to the elastic modulus of the entering sheet. A tougher sheet is more able to withstand the stresses in the corrugator. Based on a simple stress-strain analogy, a higher modulus sheet should sustain less deformation for a given stress; or stated the other way, the sheet should sustain a higher stress for a given strain. Since the level of strain in the flutes is relatively fixed, the capacity to sustain stress should increase as the modulus increases. Thus the stresses may not exceed the limiting or debonding stresses which would lead to strength loss.

Furnish differences were seen in both compressive strength and converting strength ratio. Most of the furnish effects could be expressed in terms of the elastic properties of the sheet. However, other sheet properties could also have been important, but were not measured. Strength loss can be reduced by increasing the elastic modulus or stiffness of the entering sheet. The most convenient way to increase the sheet stiffness is through densification which is generally improved through increased refining or wet pressing. It may also be possible to reduce strength loss through manipulation of sheet elastic or strength ratio by means of fiber orientation and/or machine restraint (both MD and CD). A third option is to change the fiber modulus through changes in species, fiber source or possibly refining or chemical treatment.

Formation may also play a role but this could not be directly measured in this trial. Differences between handsheet and machine paper data were not significant and tended to fall into a single group. Overall converting efficiencies for handsheets were somewhat lower than those for machine papers but these differences could be explained mainly through differences in elastic properties. For some elastic properties such as Poisson ratio it is difficult to interpret the effect on converting efficiency. The elastic properties correlate with each other to some extent and thus may not be completely independent. Thus there is no unique set of elastic properties which can be used to describe the strength loss. This makes it difficult to recommend a single set of conditions.

However, generally conditions which produced higher in-plane modulus also result in higher out-of-plane modulus. Thus most, or all, of the terms in the models tend to decrease resulting in higher converting ratio. The ratio is generally greater than one due to the stabilizing effect of the flute geometry. There is some evidence from the modified

ring compression test that the maximum ratio is in the neighborhood of 1.7. The converting ratio drops from the maximum due to debonding and other damage effects during fluting.

Hygroexpansivity also plays a significant role. This variable could affect the built-in stresses in the sheet during fluting through interactions with presteaming. However, these variables could not be entered into the model without affecting the other terms.

Both machine papers and handsheet samples were included in the model development and their effects appear to be consistent. In this set of data the OCC densifies more easily than the chemical furnishes. This resulted in a higher elastic modulus for the OCC handsheets and a higher converting ratio than seen previously with the machine papers made from OCC.

Both machine papers and handsheet samples responded similarly to corrugating when introduced at the same elastic conditions. The machine paper and handsheet data covered the scatter plot in a similar fashion.

ACKNOWLEDGEMENTS

The author wishes to thank the members of the CKPG for their support of this project. A special thanks to those members of the CKPG who supplied pulp and commercial papers for the project. Carl Smith was instrumental in developing the modified fluted edge crush test and in the design of the FEC test device. Carl also performed the corrugating runs.

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Figure 1

Plan Flow - Handsheets

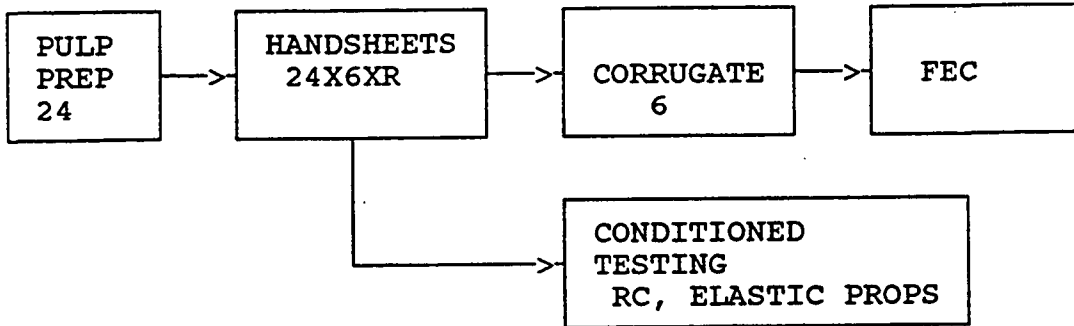


Figure 2

Plan Flow - Machine Papers

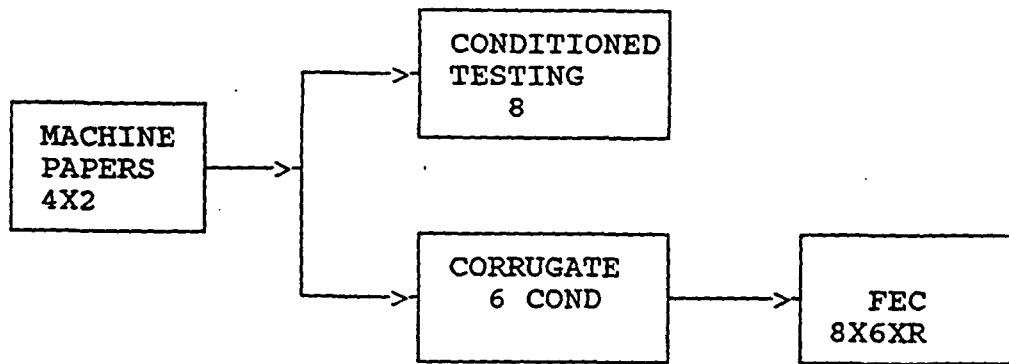


Figure 3

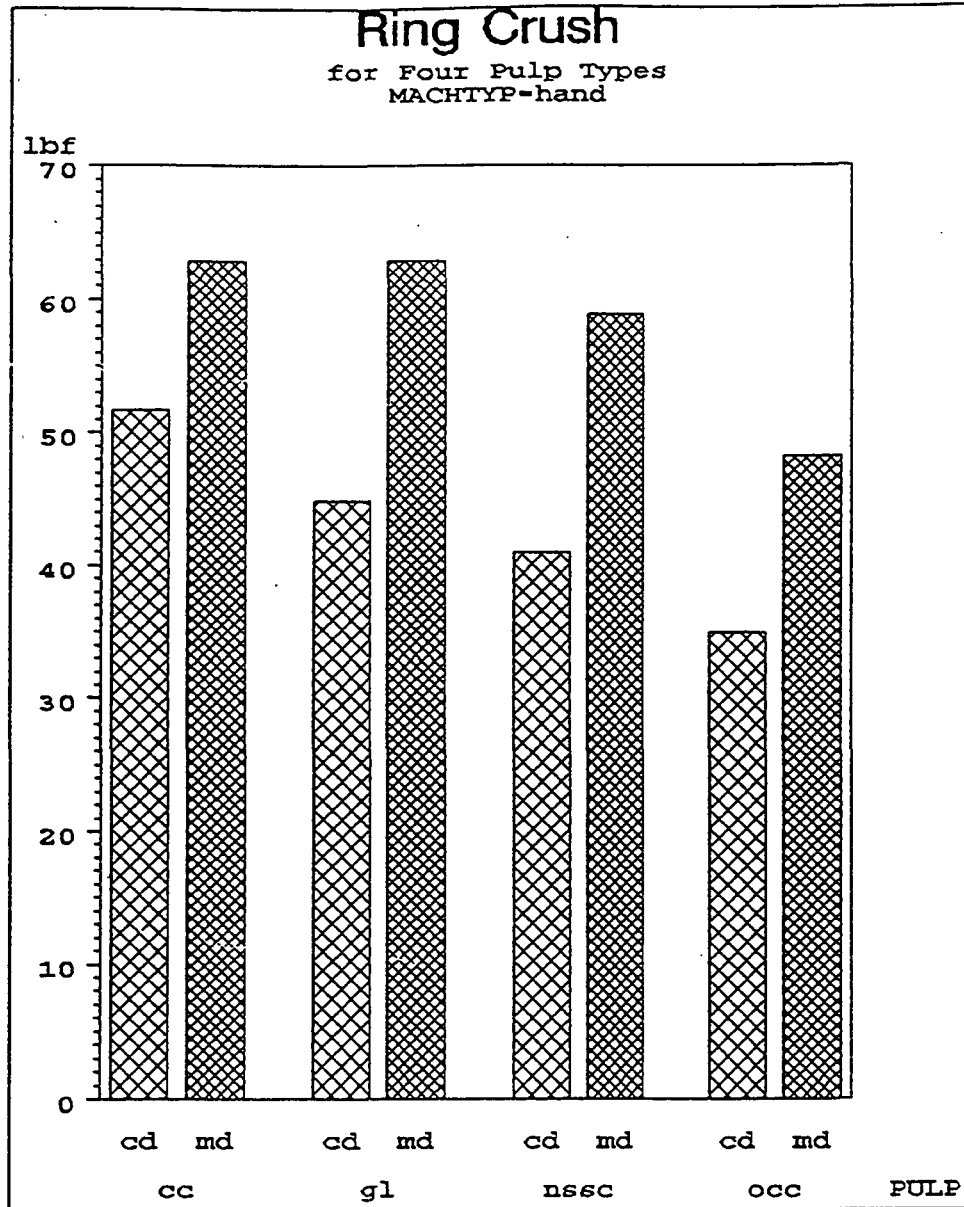


Figure 4

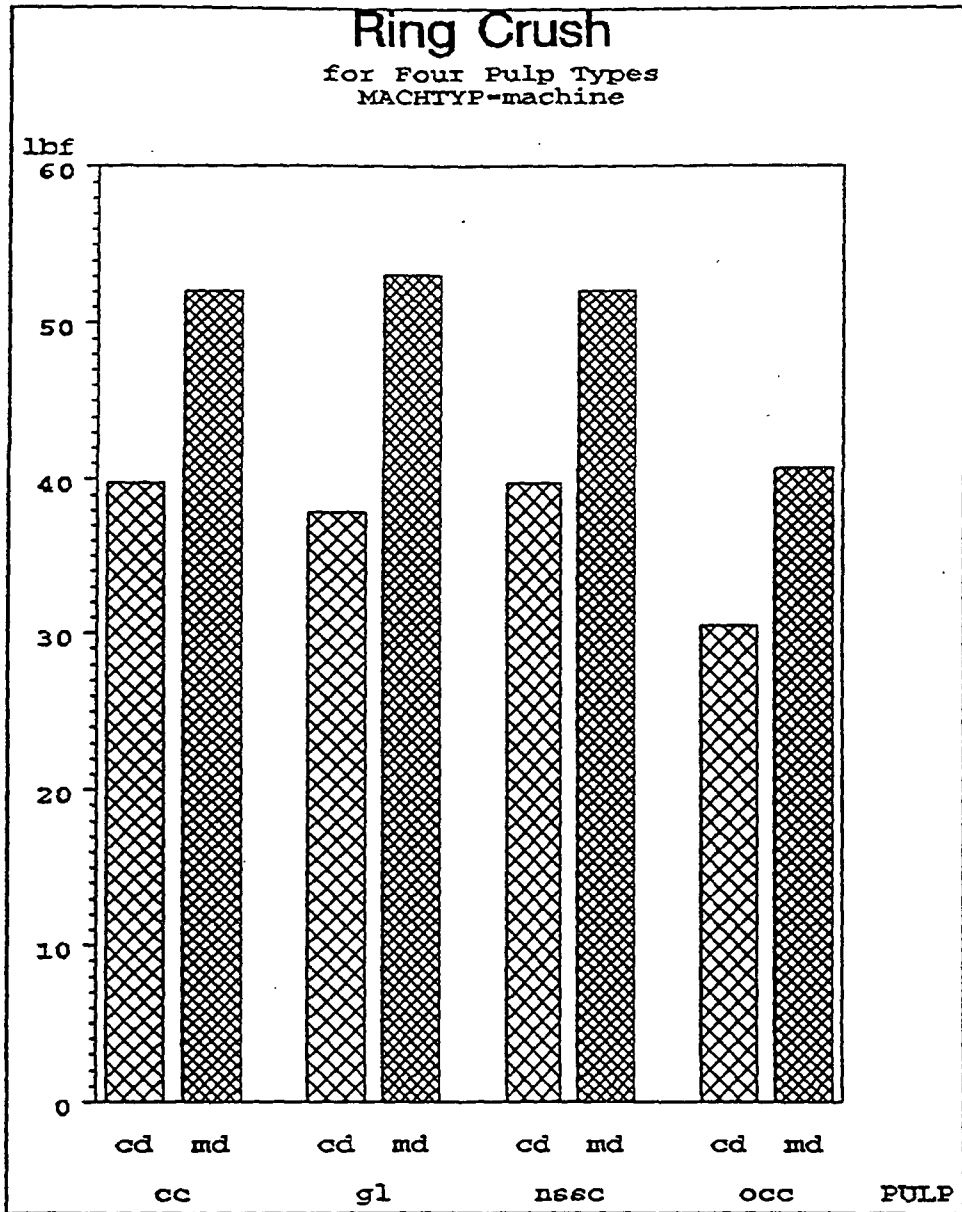


Figure 5

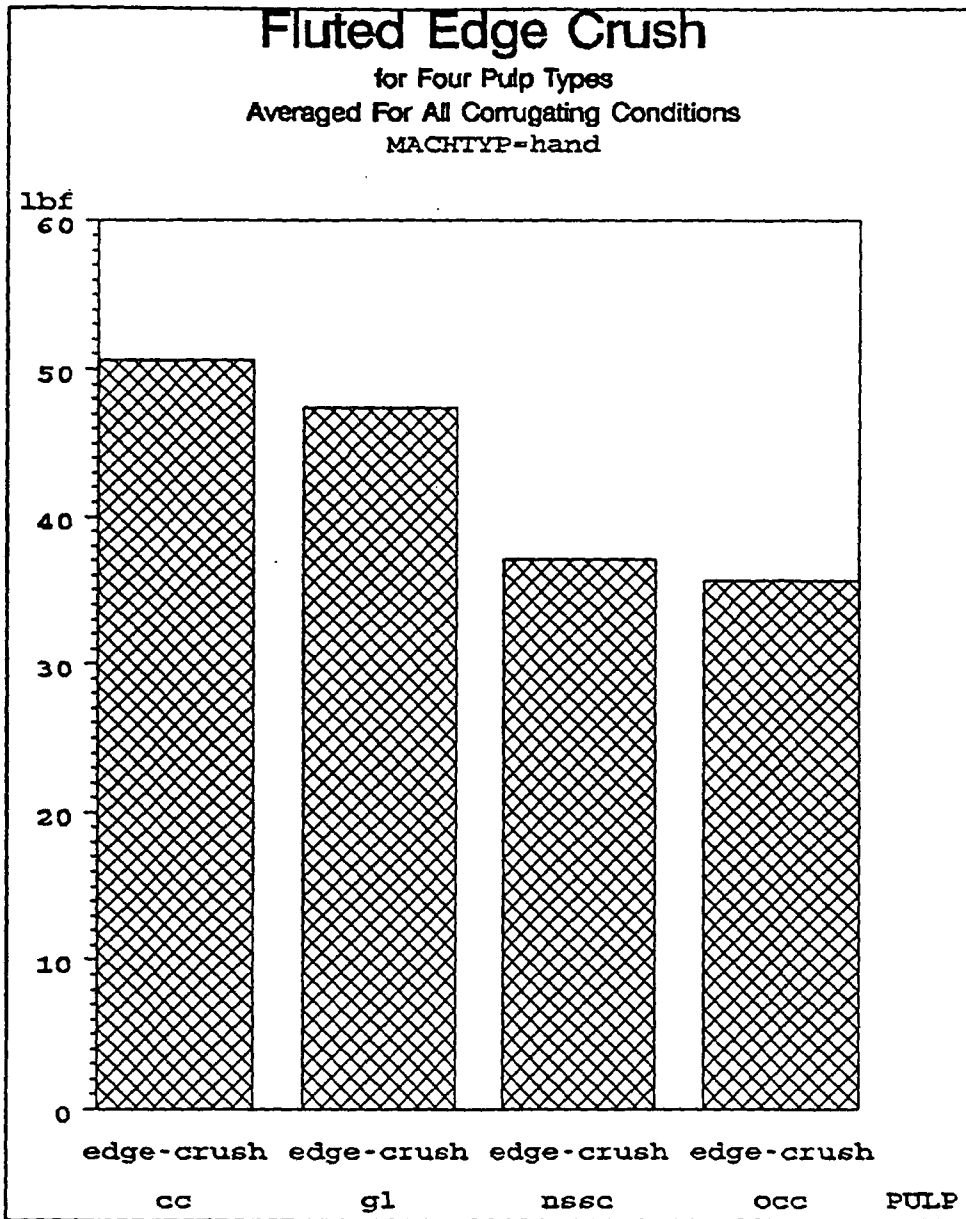


Figure 6

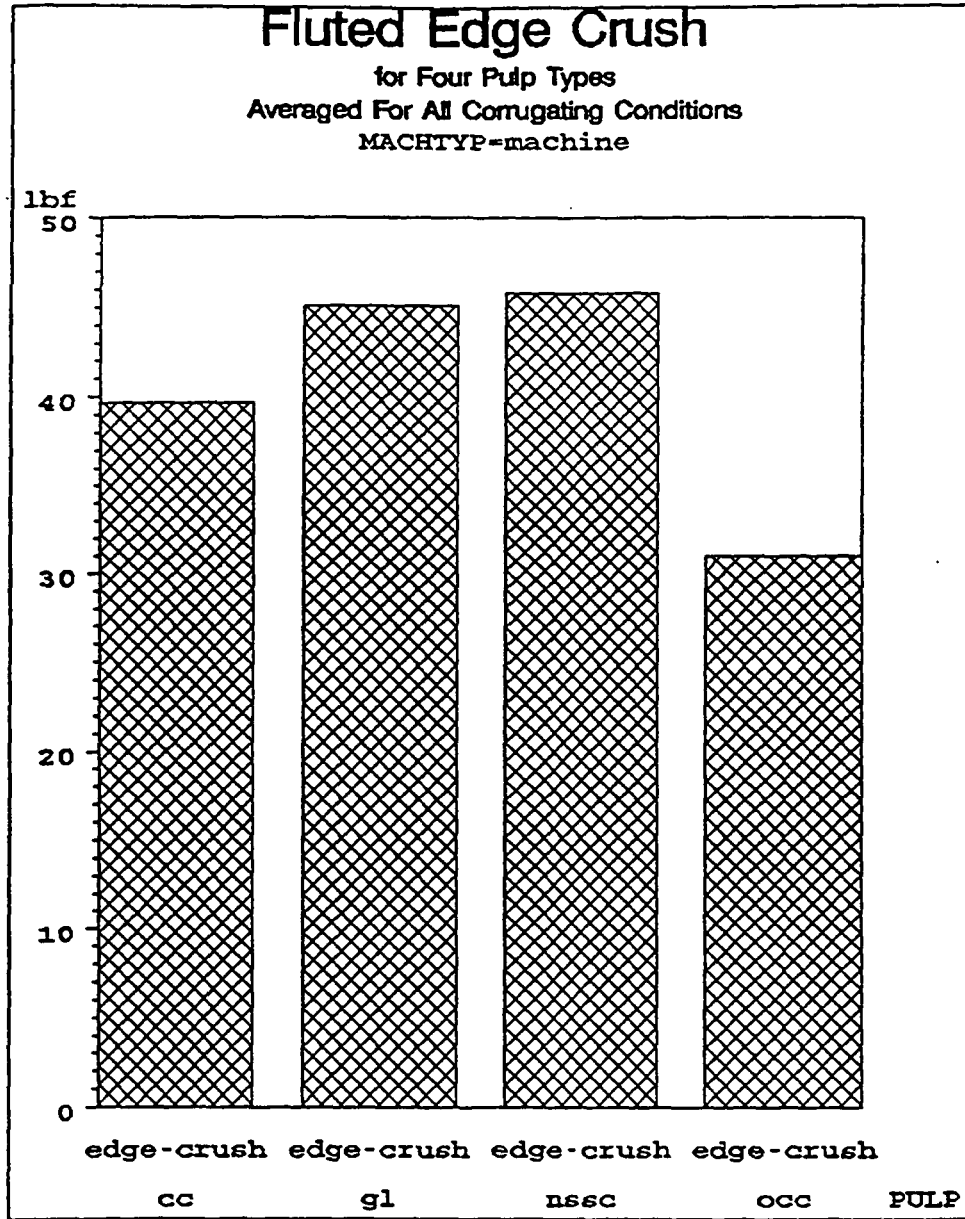


Figure 7

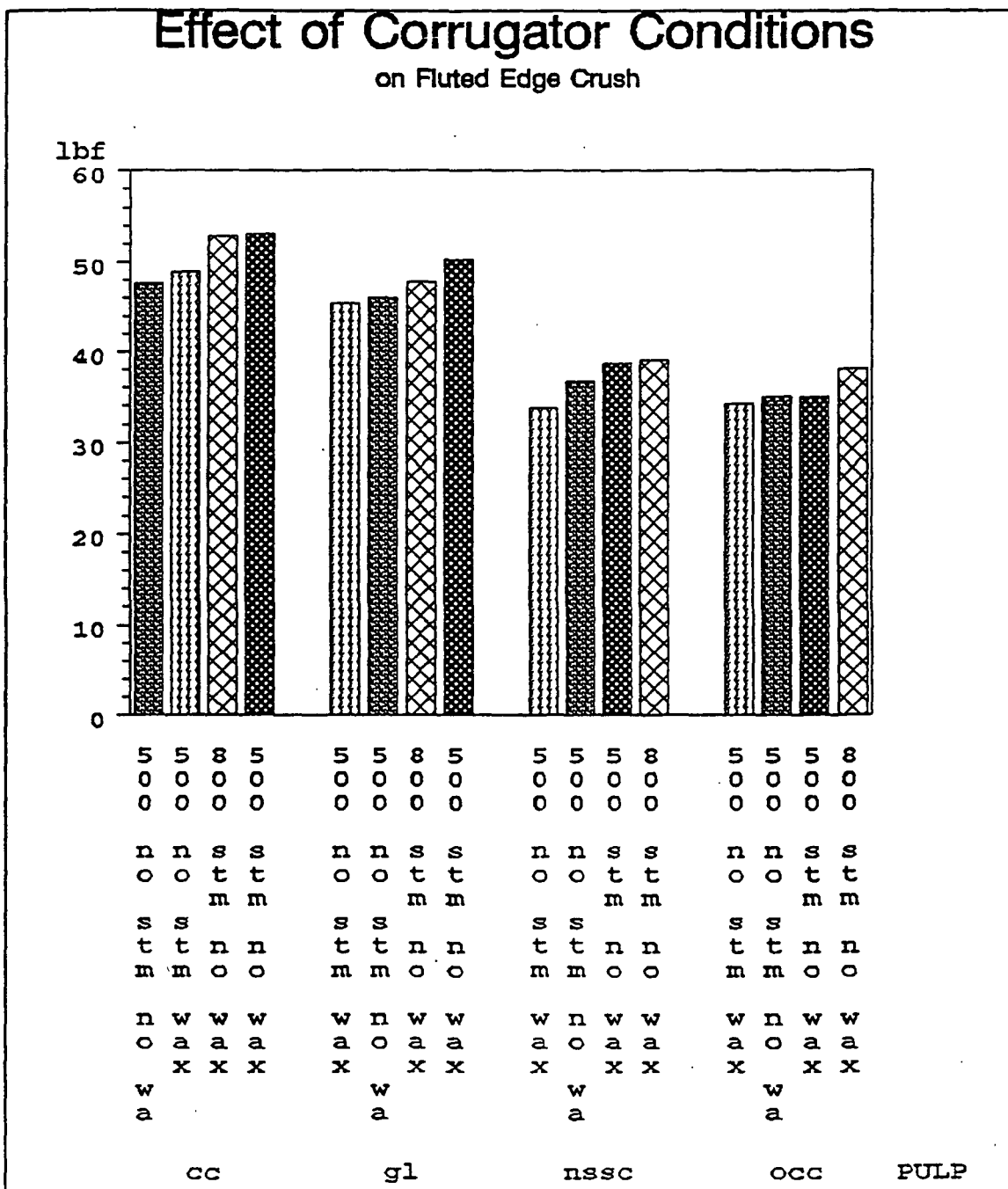
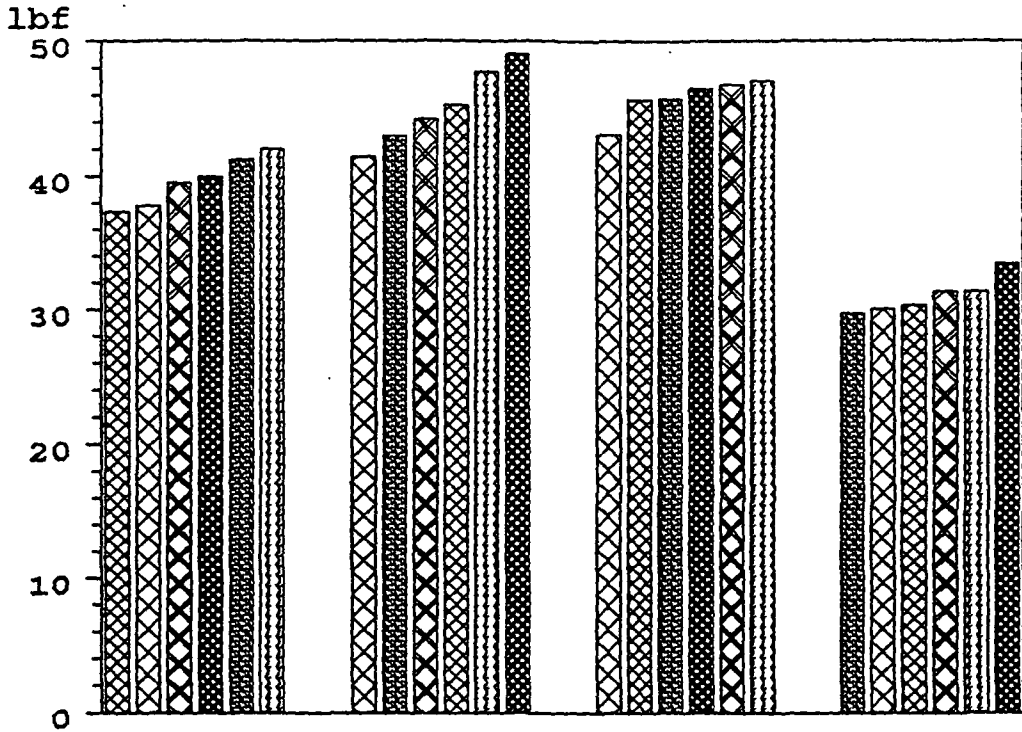


Figure 8

Effect of Corrugator Conditions on Fluted Edge Crush



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 000000 000000 000000 000000

nnssnn nnsnns nnnssn nnnsns
 oottoo ootoot oootto oootot
 mm m m mm m m
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cc

gl

nssc

occ

PULP

Figure 9

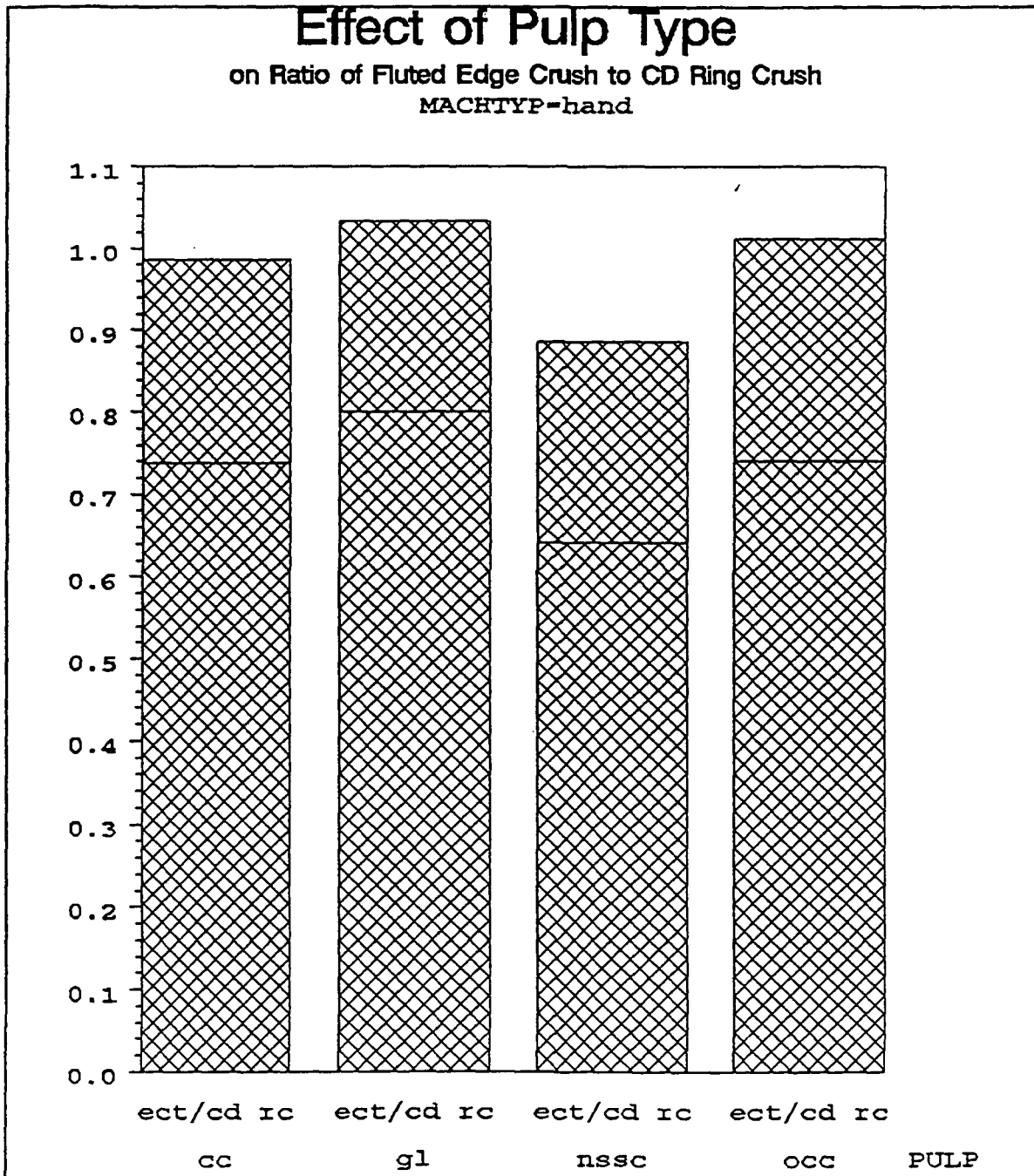


Figure 10

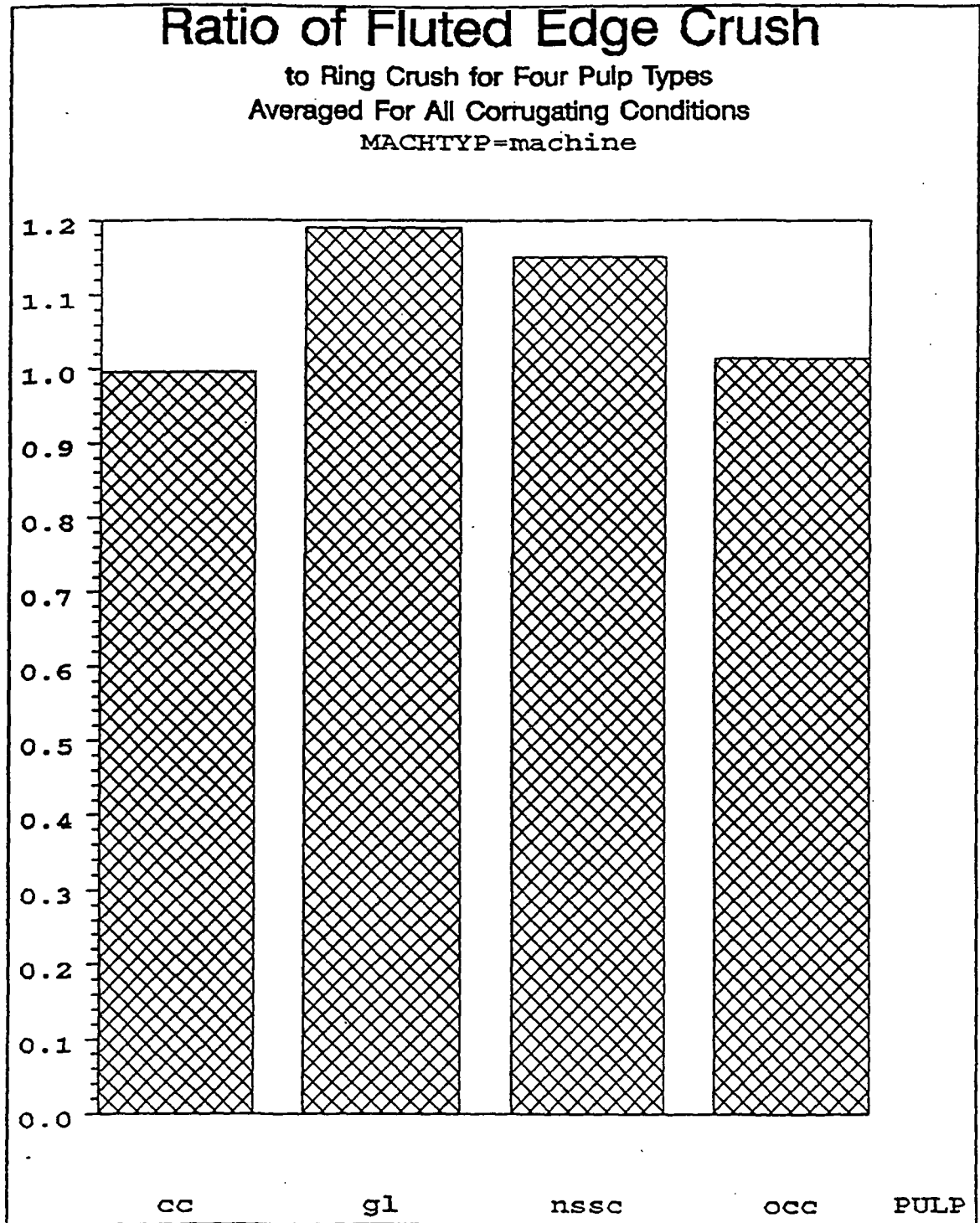


Figure 11

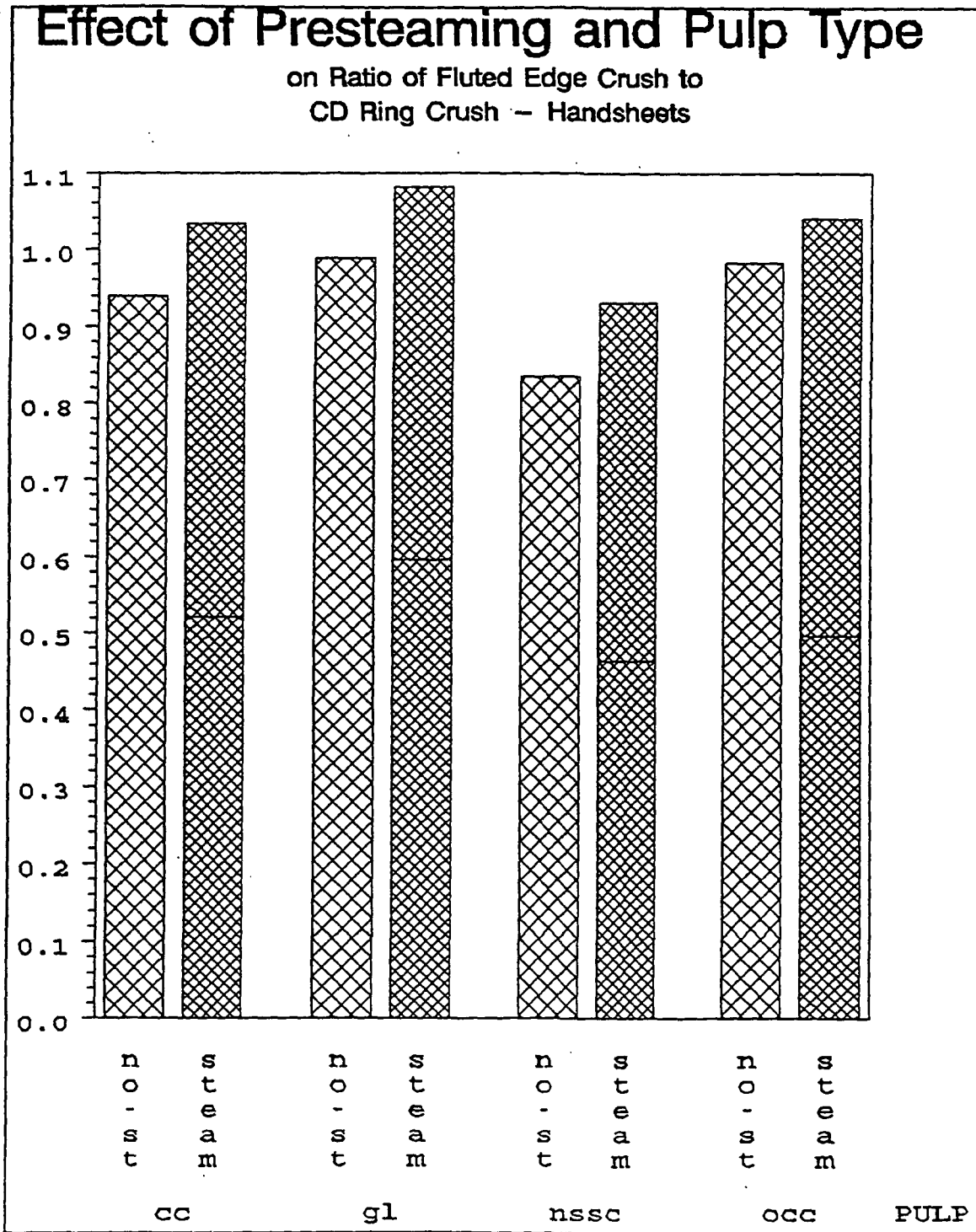


Figure 12

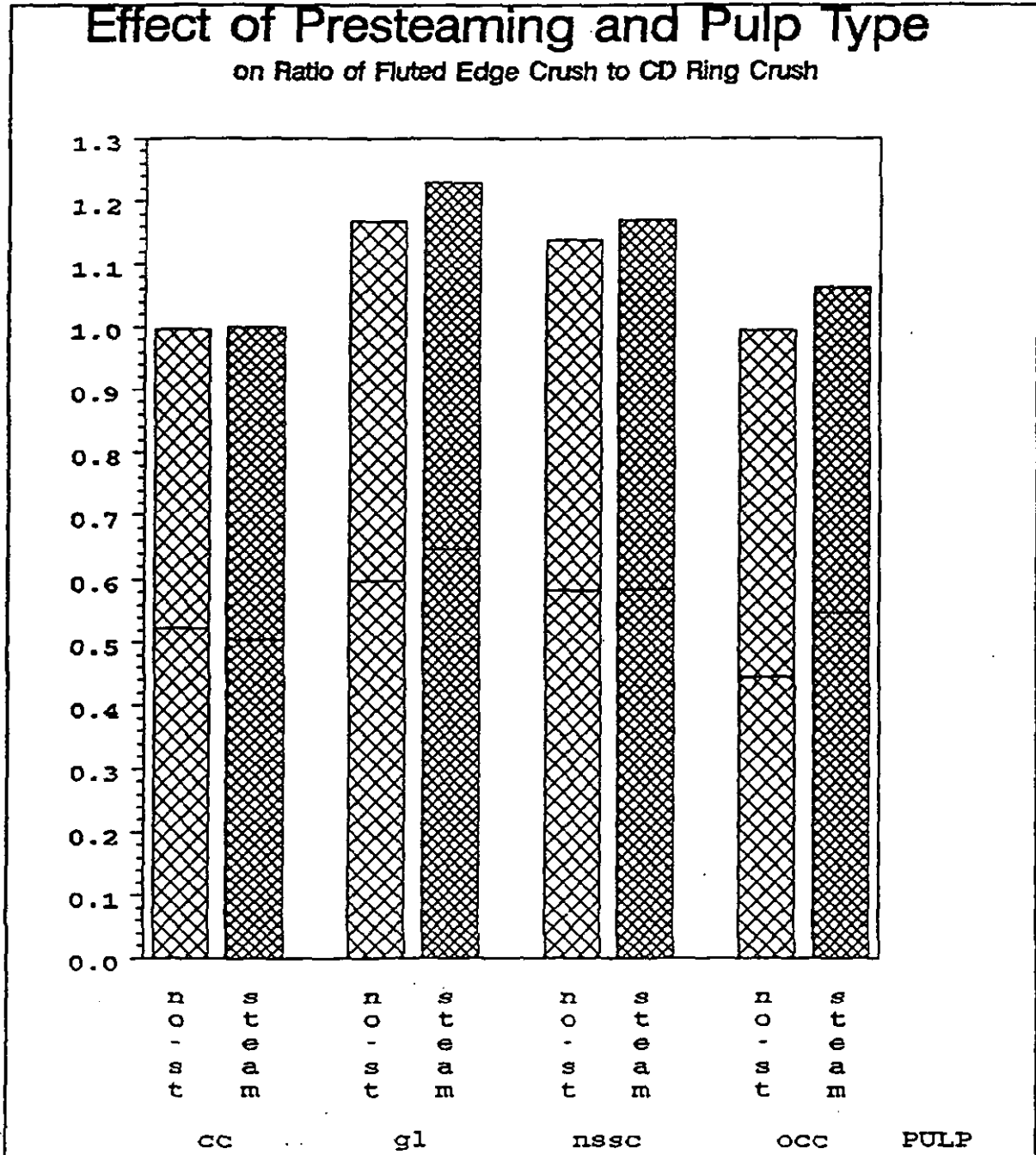


Figure 13

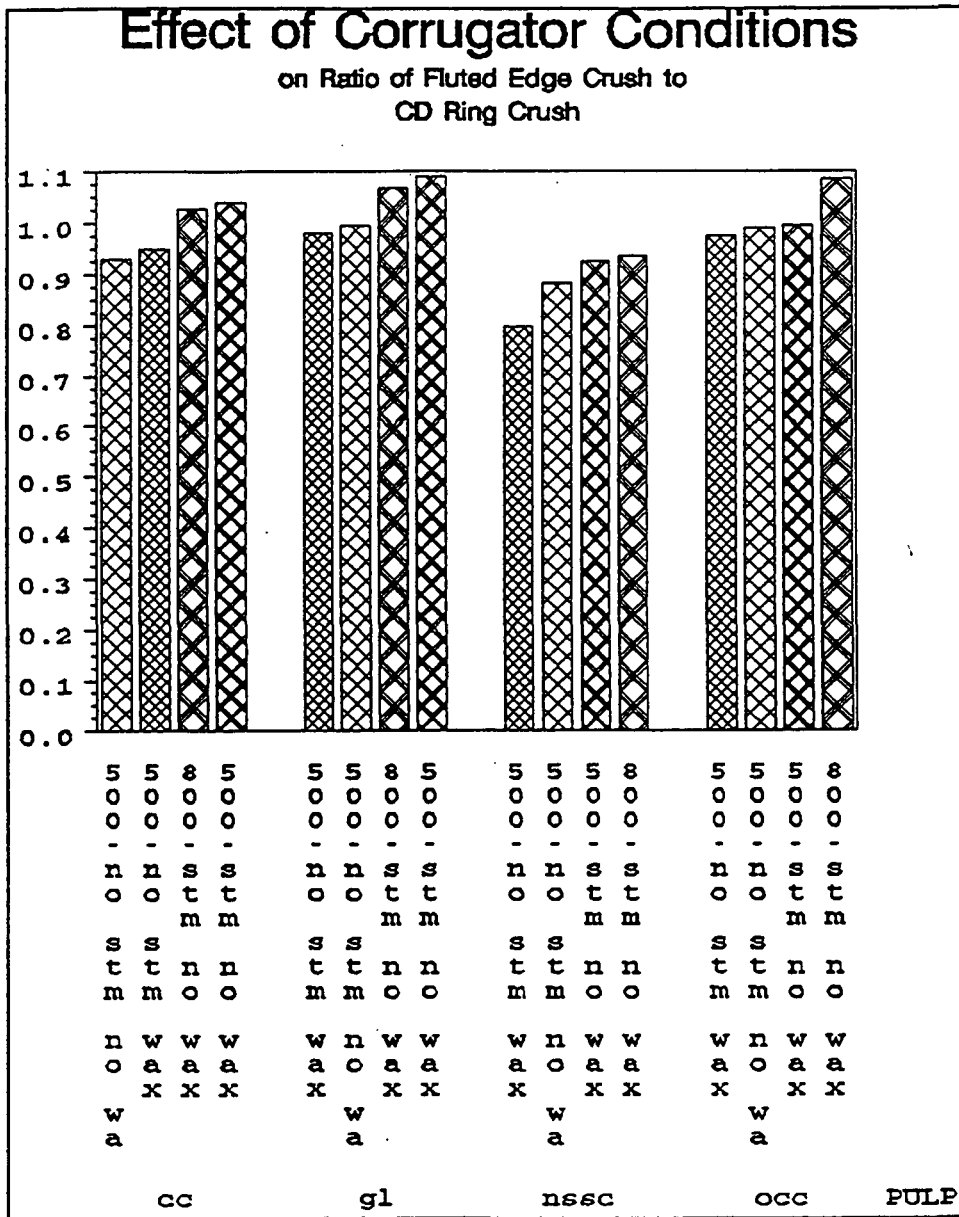


Figure 14

Effect of Corrugator Conditions on Ratio of Fluted Edge Crush to CD Ring Crush

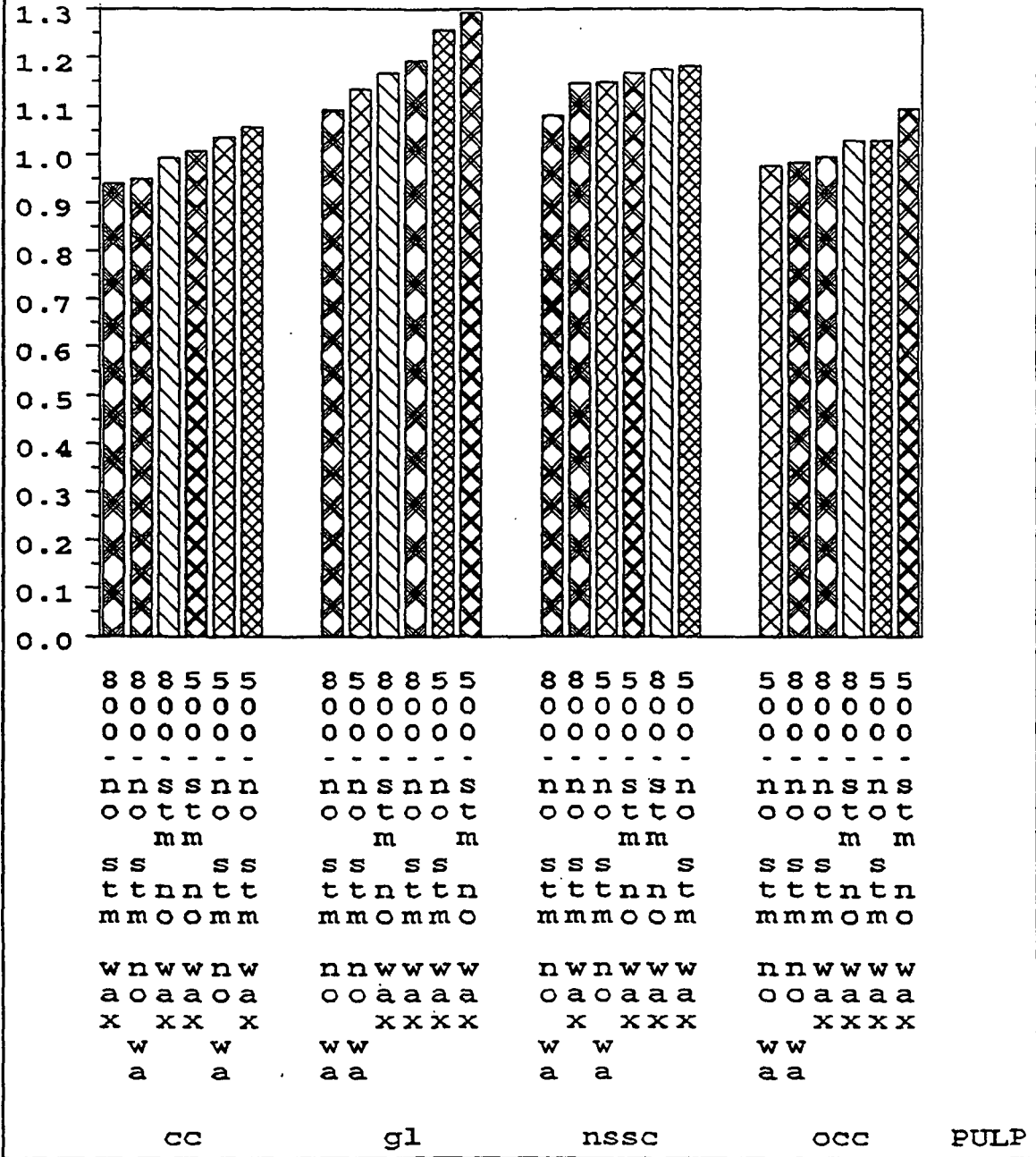


Figure 15

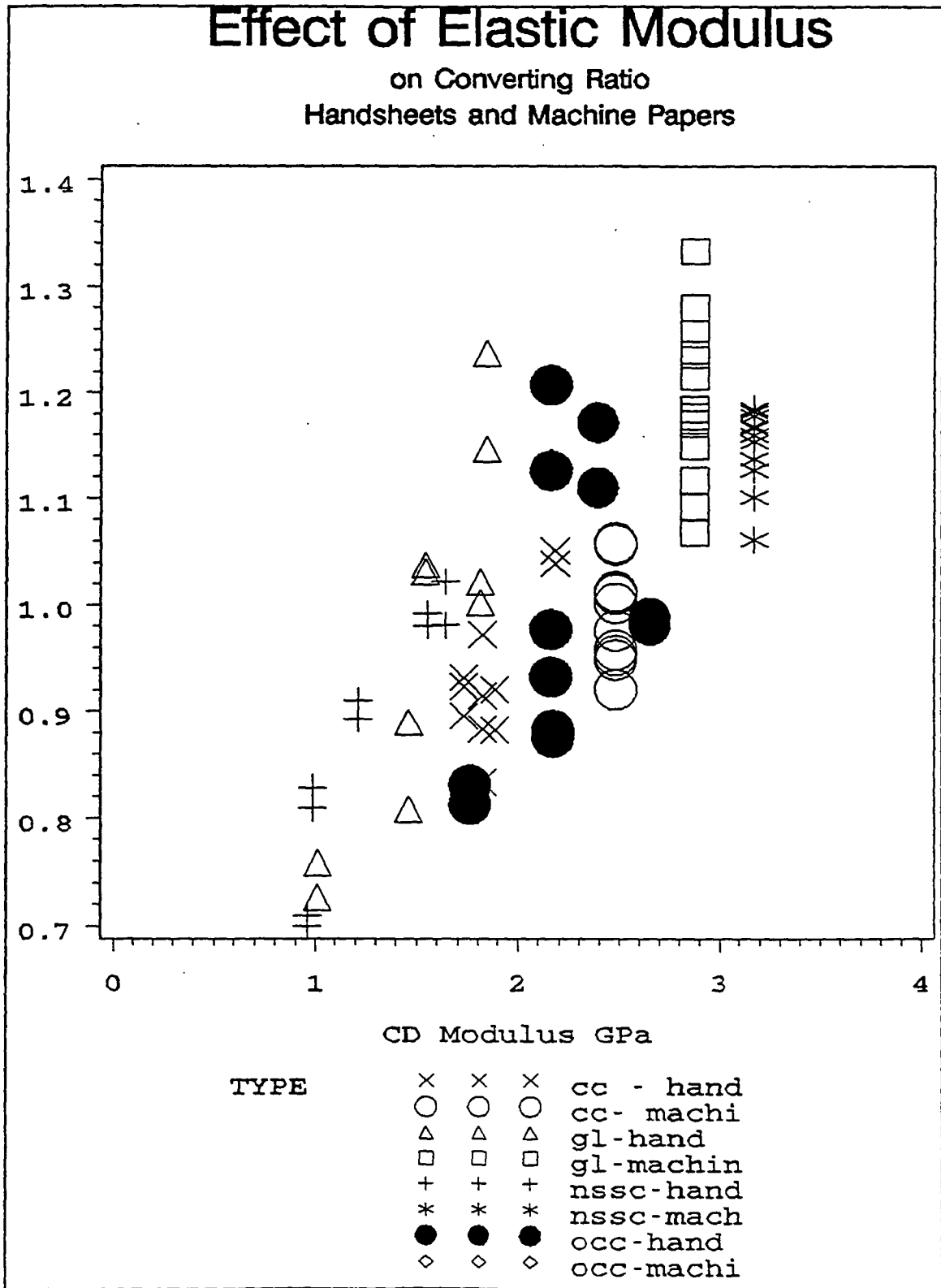


Figure 16

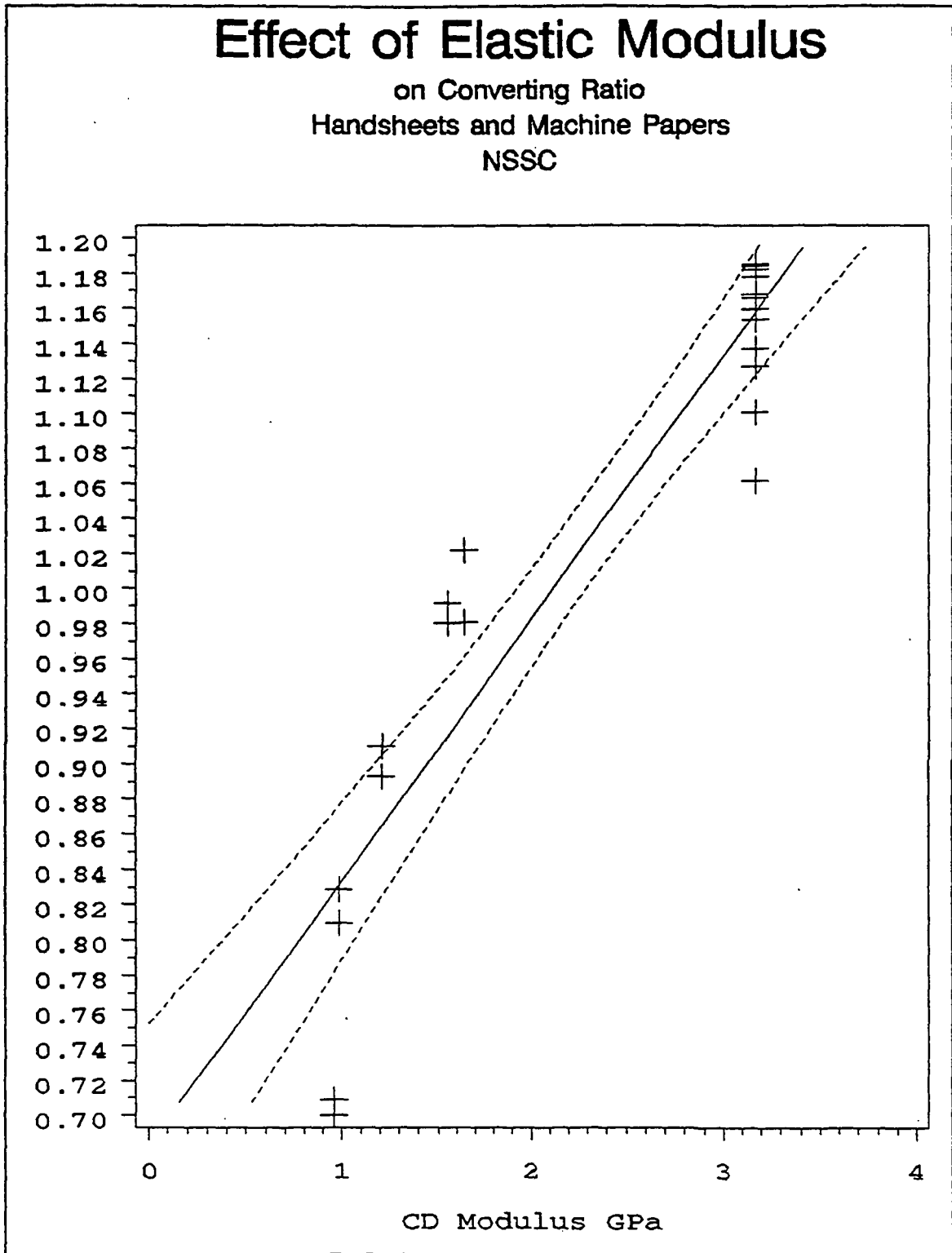


Figure 17

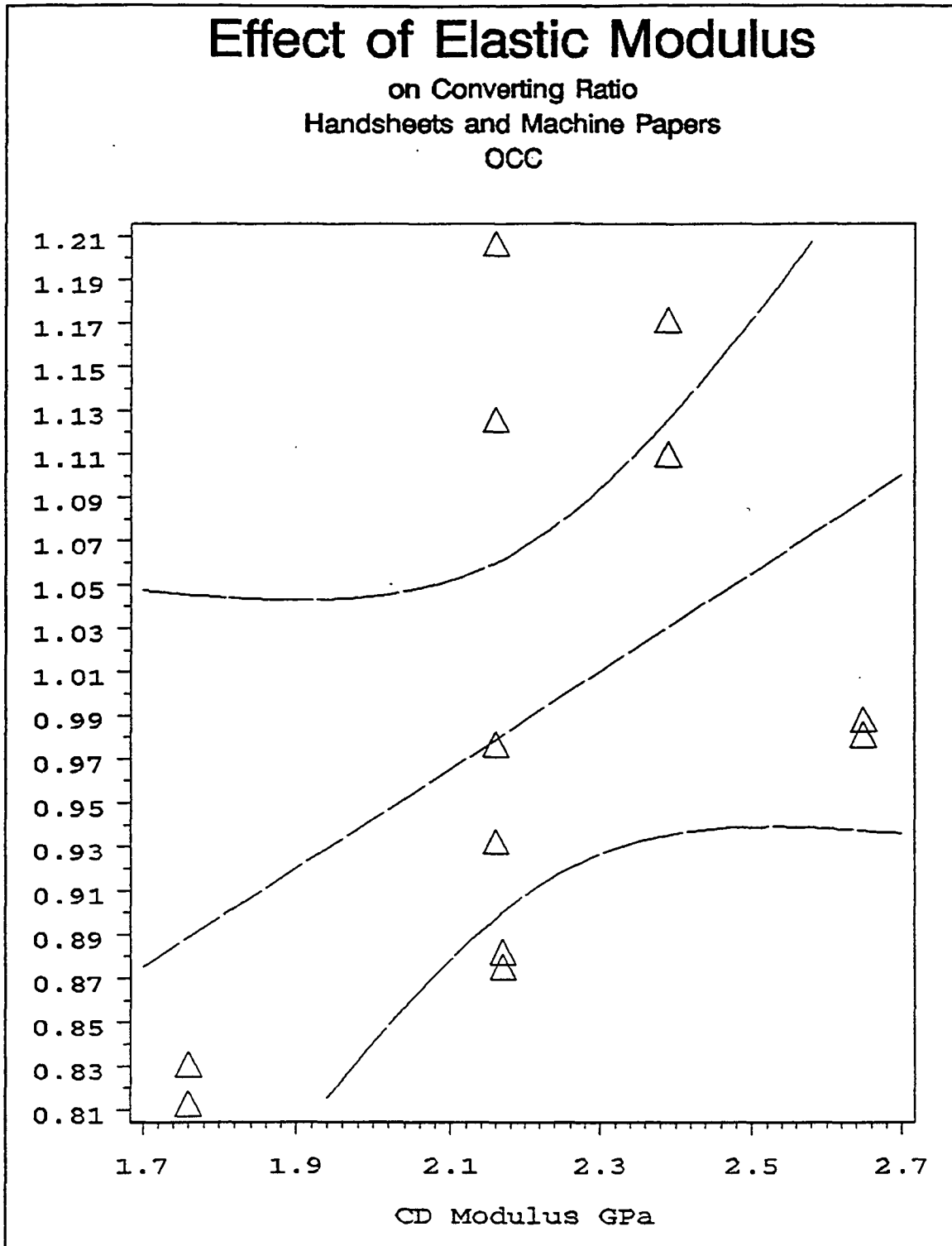


Figure 18

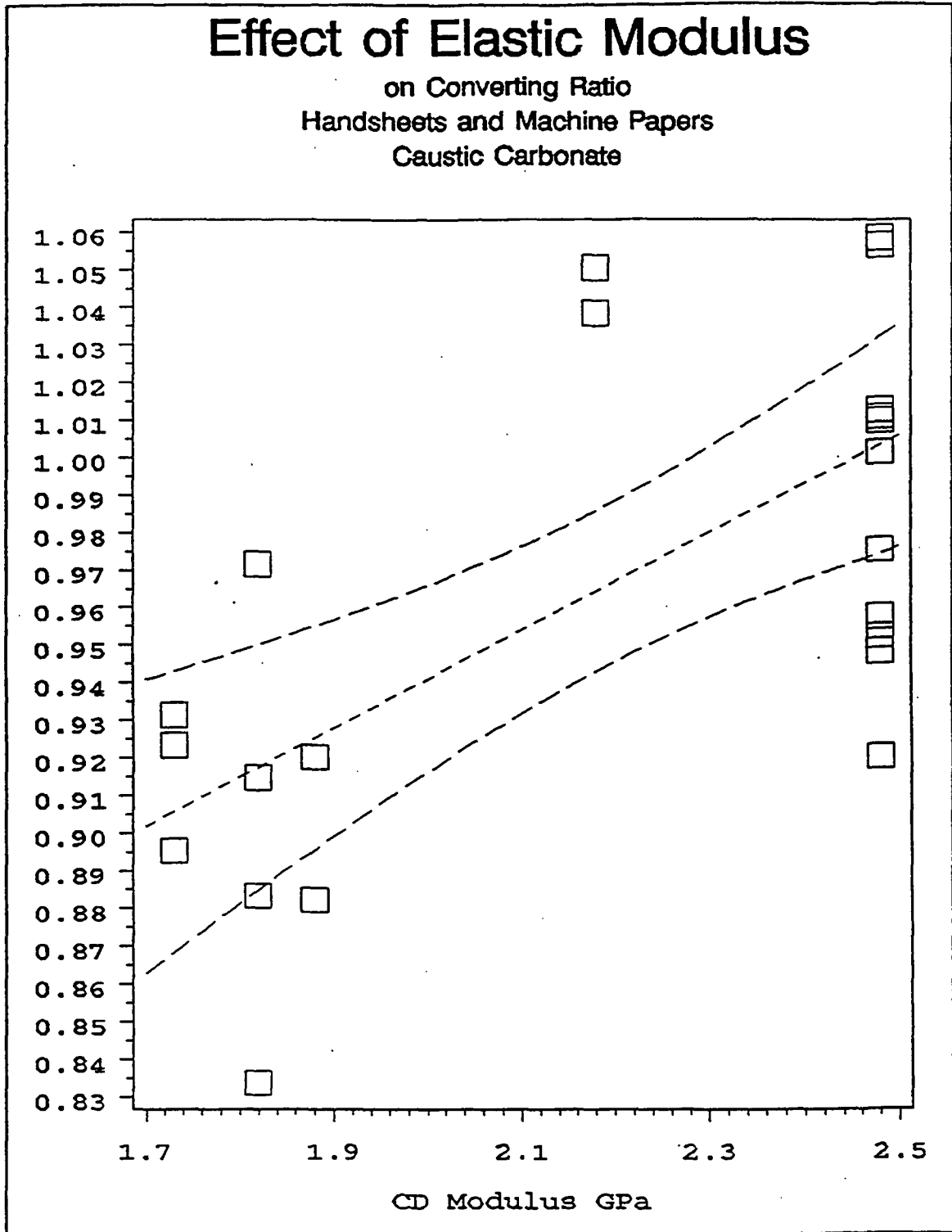


Figure 19

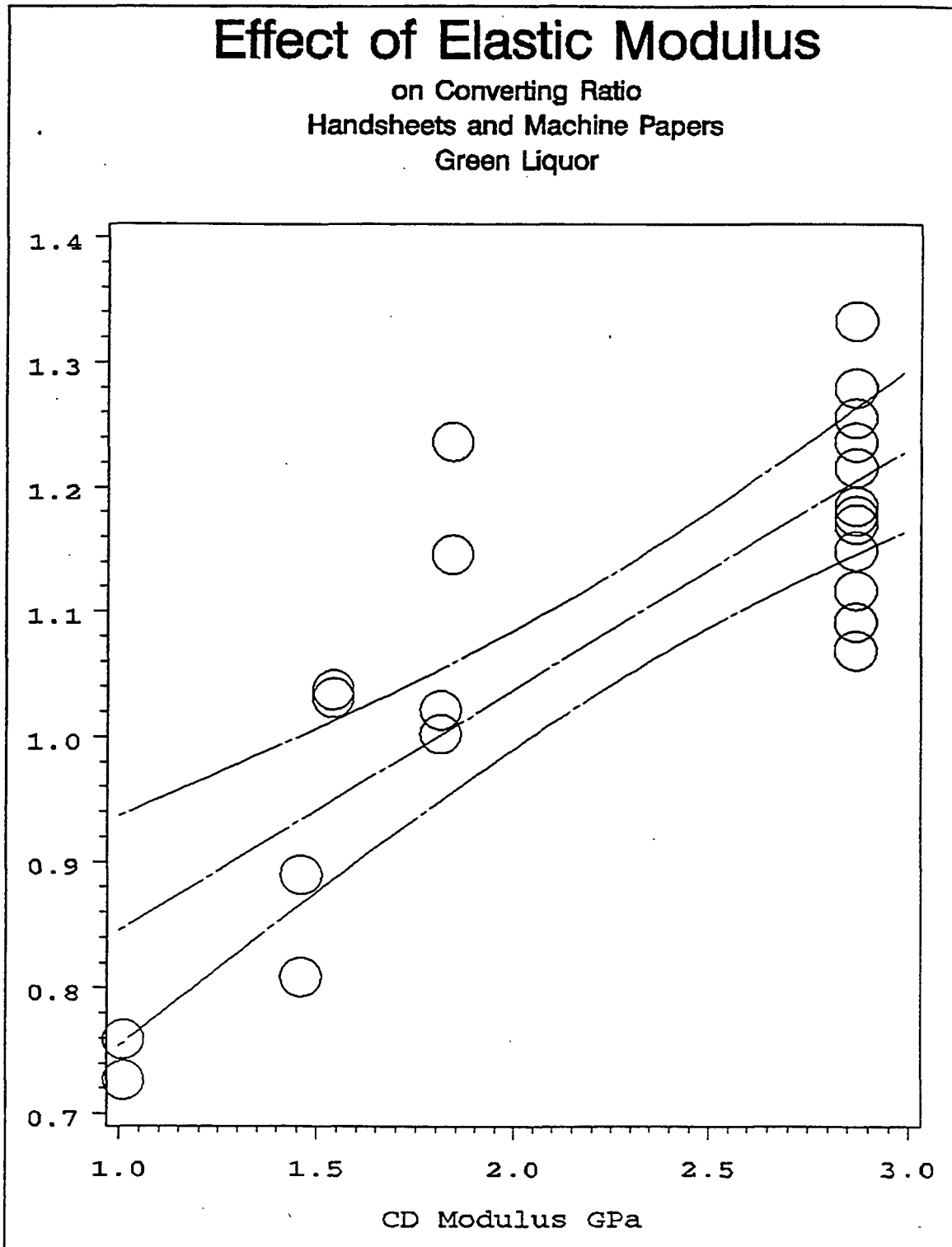


Figure 20

Effect of Specific Elastic Modulus

on Converting Ratio
Handsheets and Machine Papers

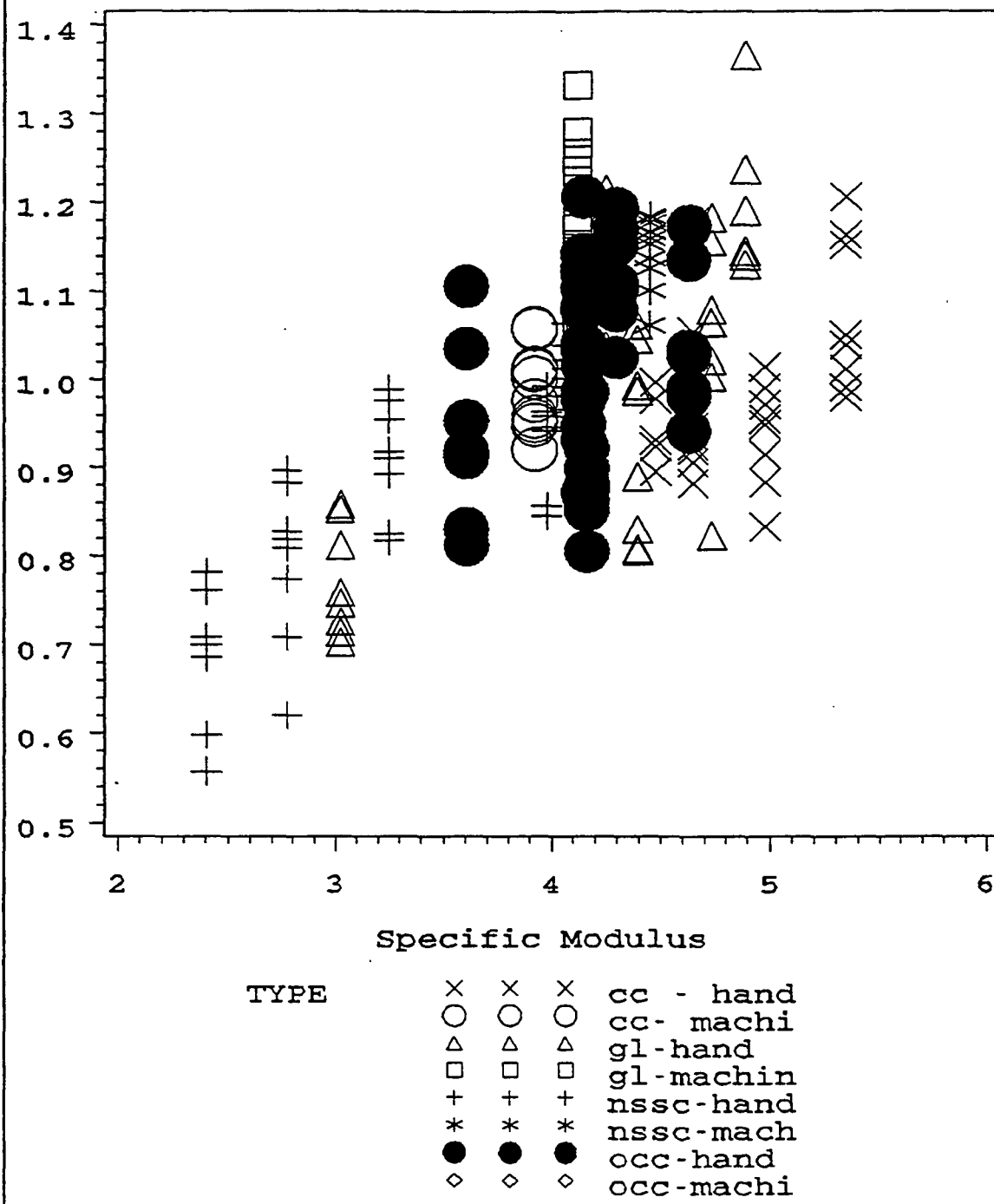
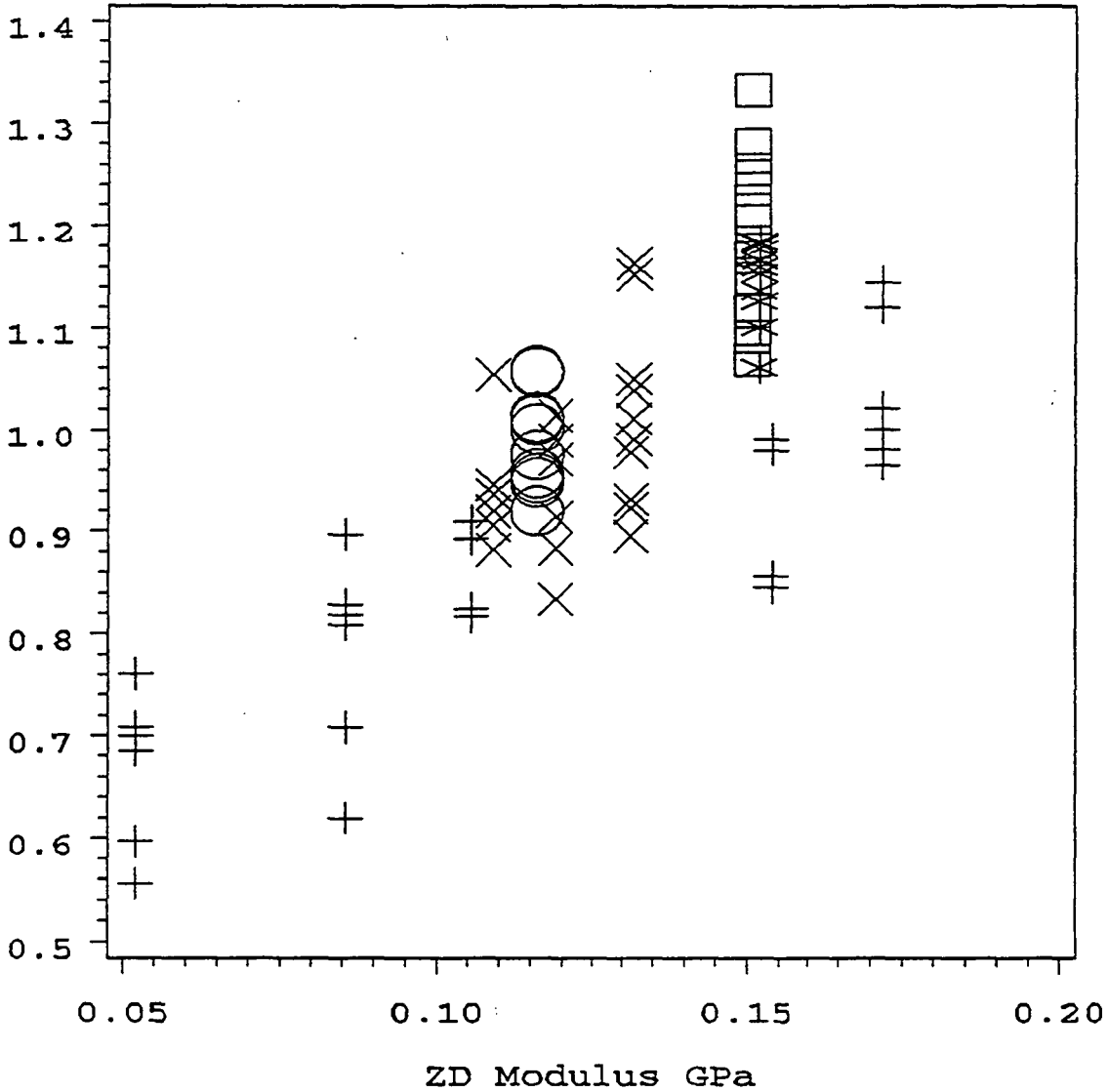


Figure 21

Effect of ZD Elastic Modulus on Converting Ratio Handsheets and Machine Papers



TYPE	Symbol	Symbol	Symbol	Description
	x	x	x	cc - hand
	○	○	○	cc- machi
	△	△	△	gl-hand
	□	□	□	gl-machin
	+	+	+	nssc-hand
	*	*	*	nssc-mach
	●	●	●	occ-hand
	◇	◇	◇	occ-machi

Figure 22

Effect of ZD Elastic Modulus on Converting Ratio Handsheets and Machine Papers NSSC

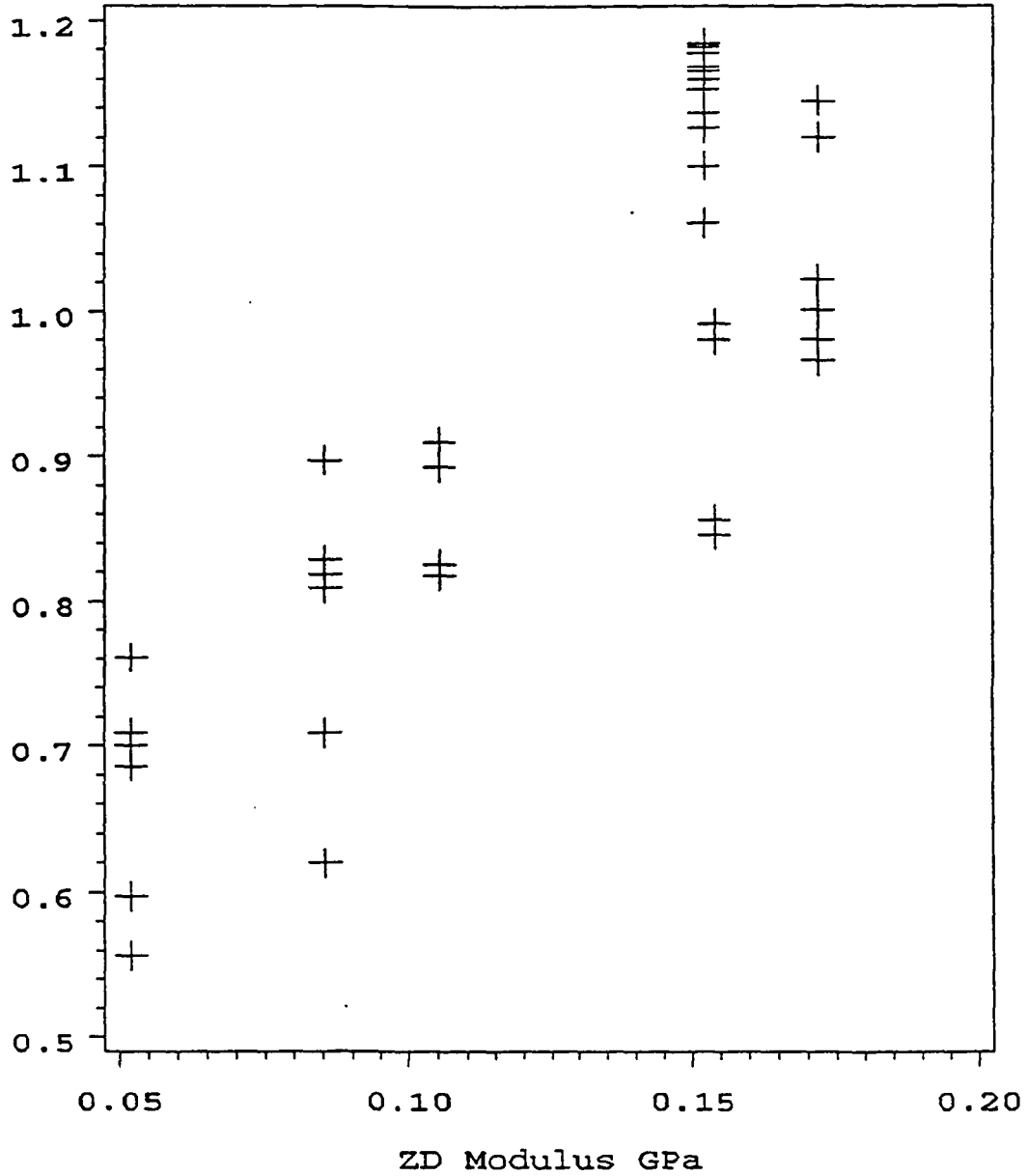
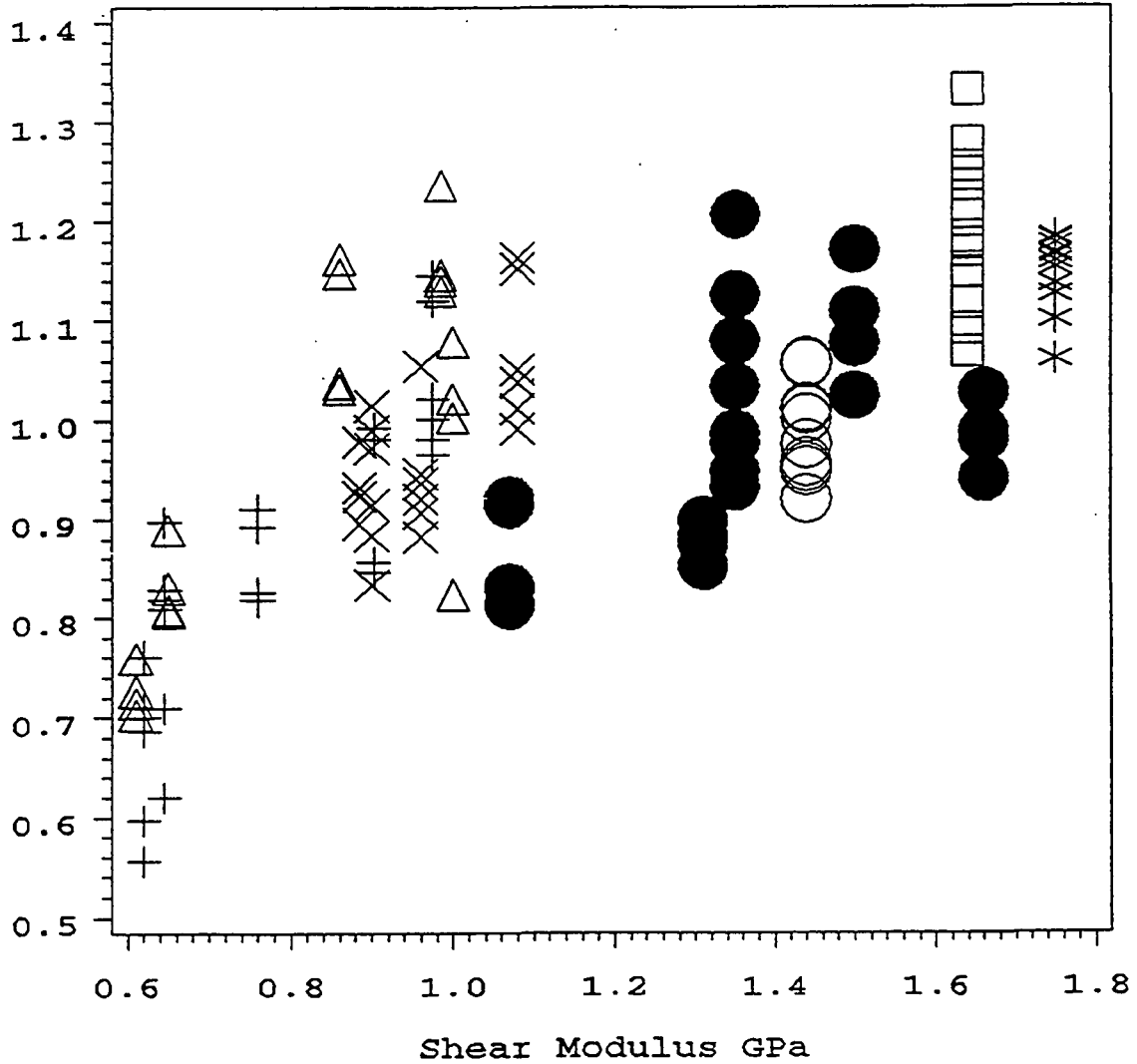


Figure 23

Effect of Elastic Shear Modulus on Converting Ratio Handsheets and Machine Papers



TYPE	×	×	×	cc - hand
	○	○	○	cc- machi
	△	△	△	gl-hand
	□	□	□	gl-machin
	+	+	+	nssc-hand
	*	*	*	nssc-mach
	●	●	●	occ-hand
	◇	◇	◇	occ-machi

Figure 24

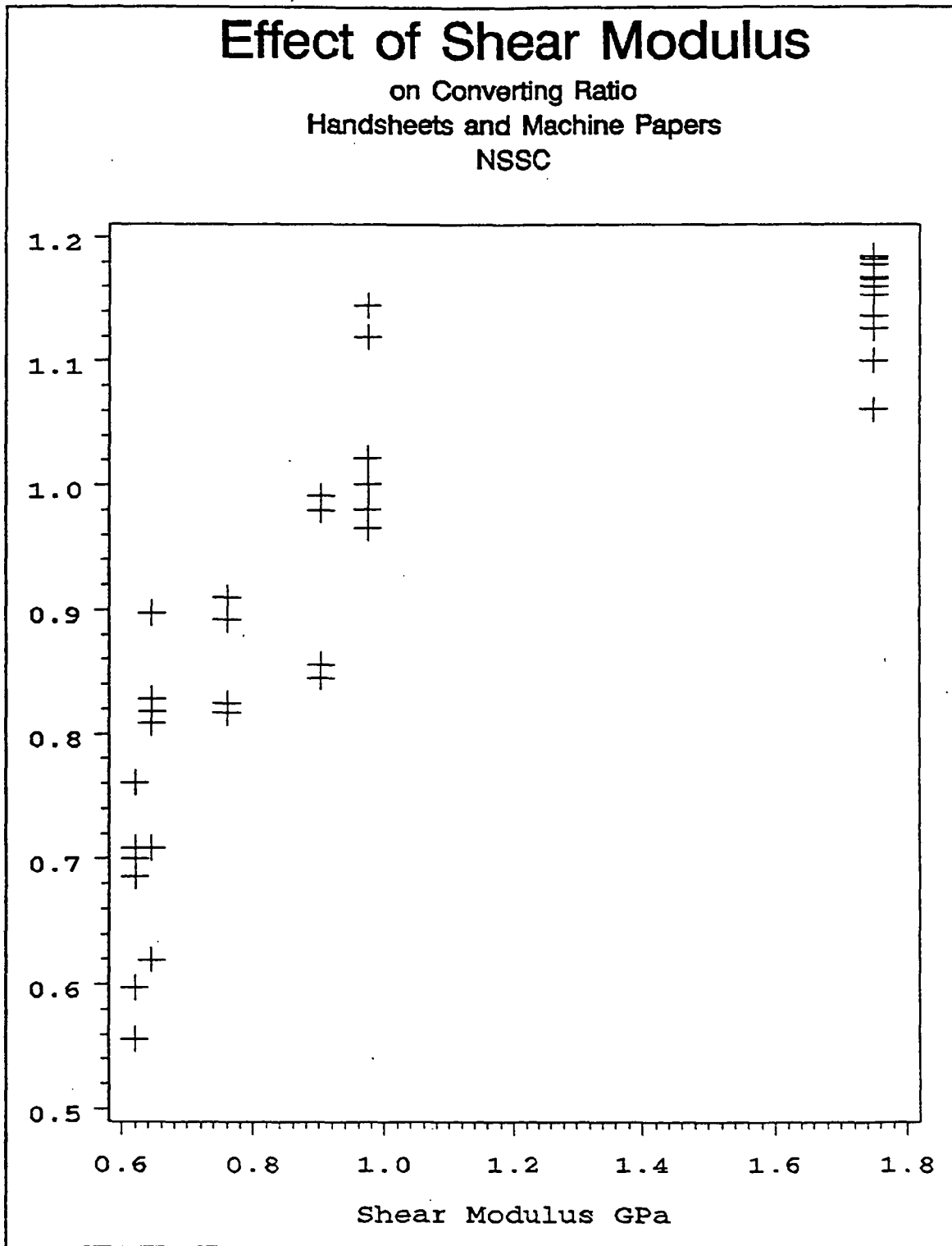


Figure 25

Effect of Shear Modulus

on Converting Ratio
Handsheets and Machine Papers
OCC

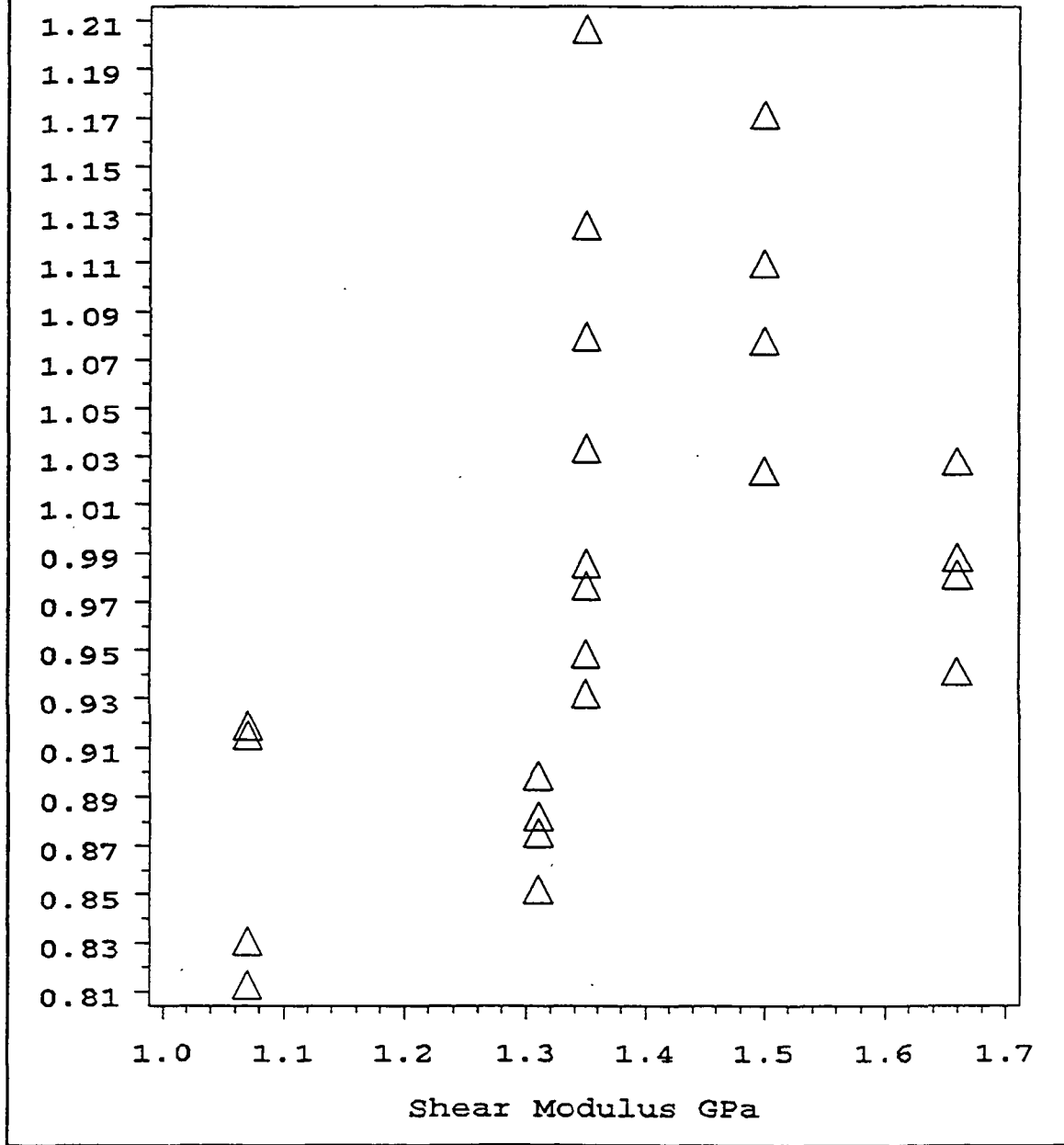


Figure 26

Effect of Shear Modulus

on Converting Ratio
Handsheets and Machine Papers
Caustic Carbonate

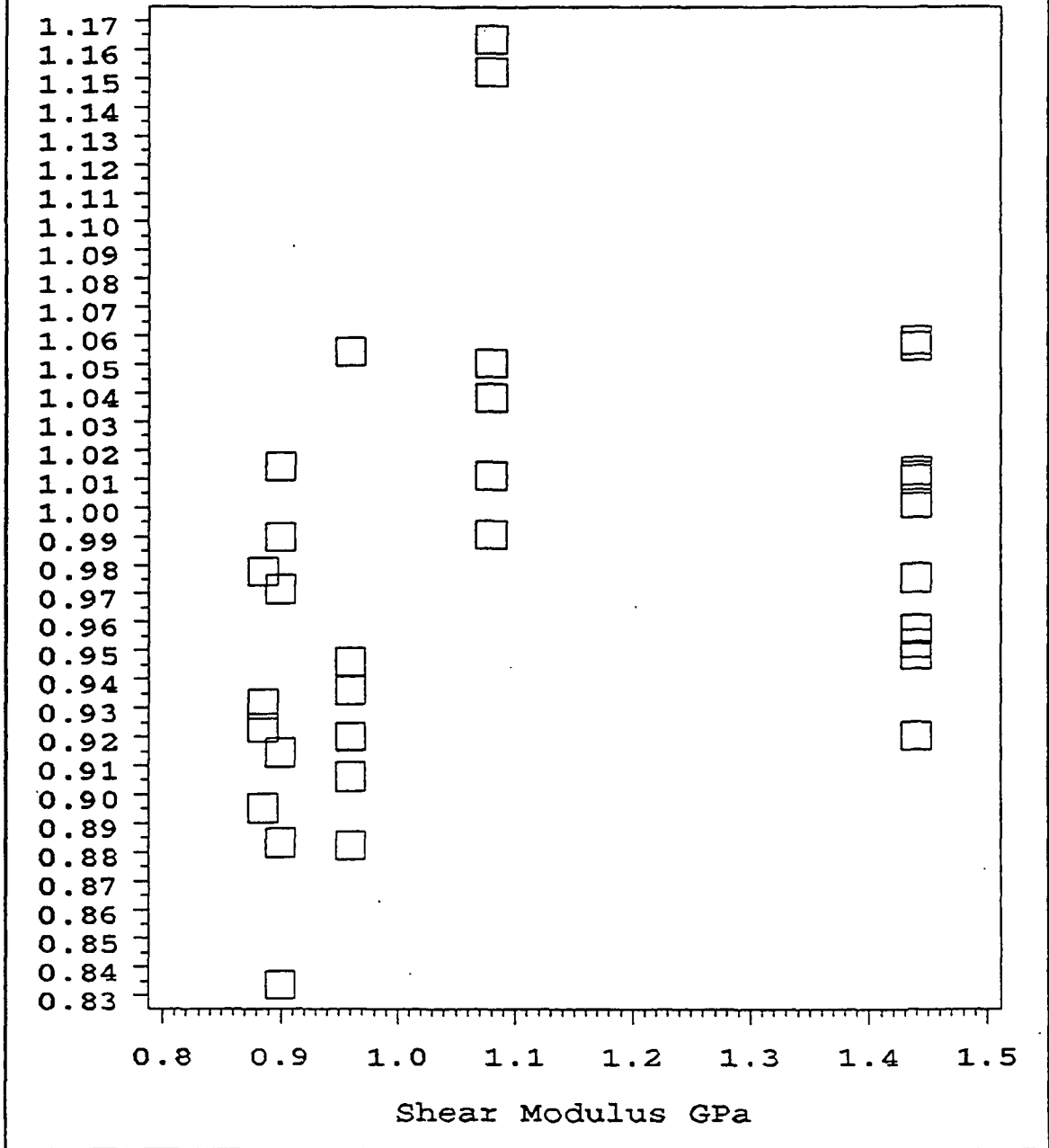


Figure 27

Effect of Shear Modulus

on Converting Ratio
Handsheets and Machine Papers
Green Liquor

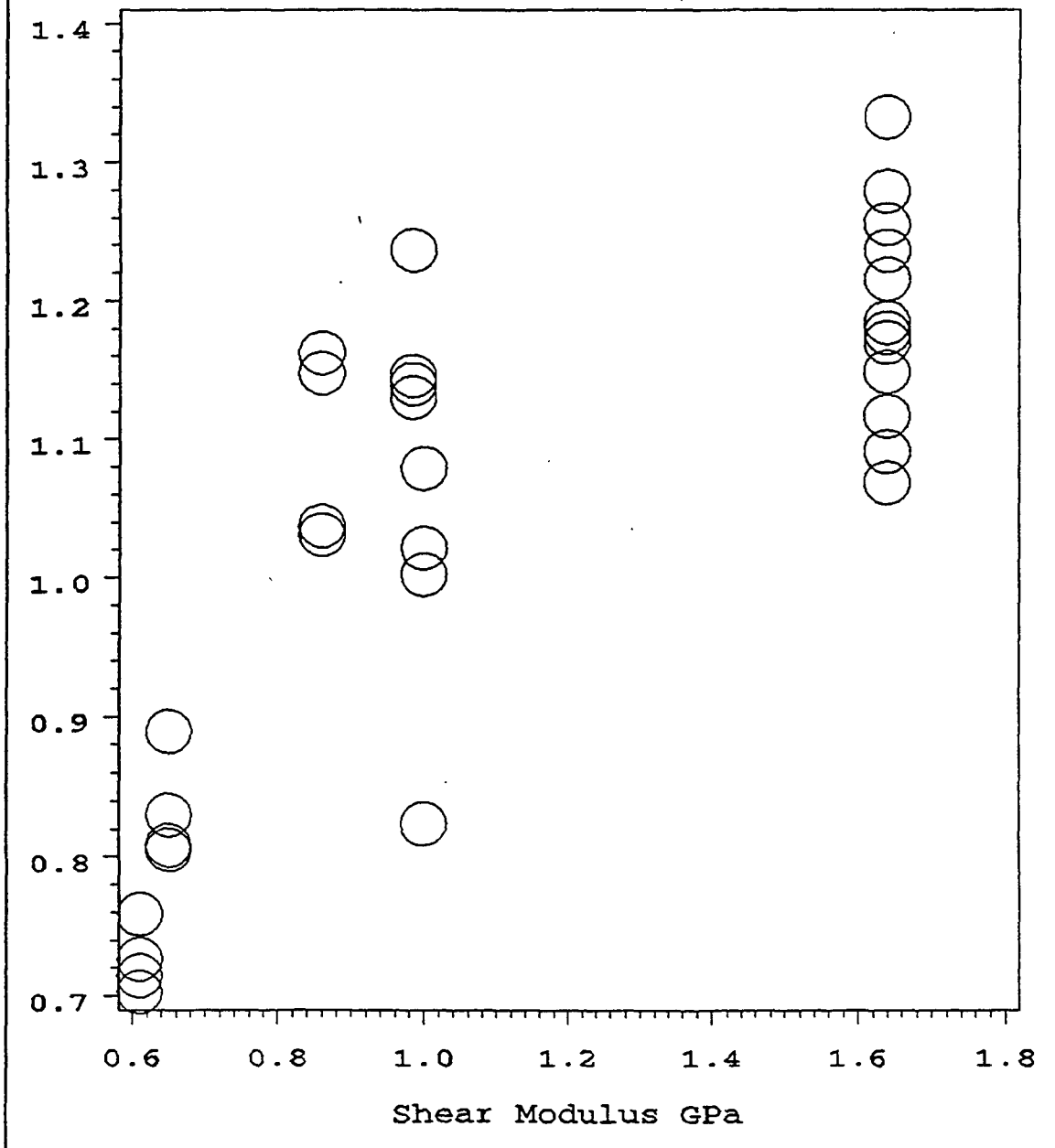


Figure 28

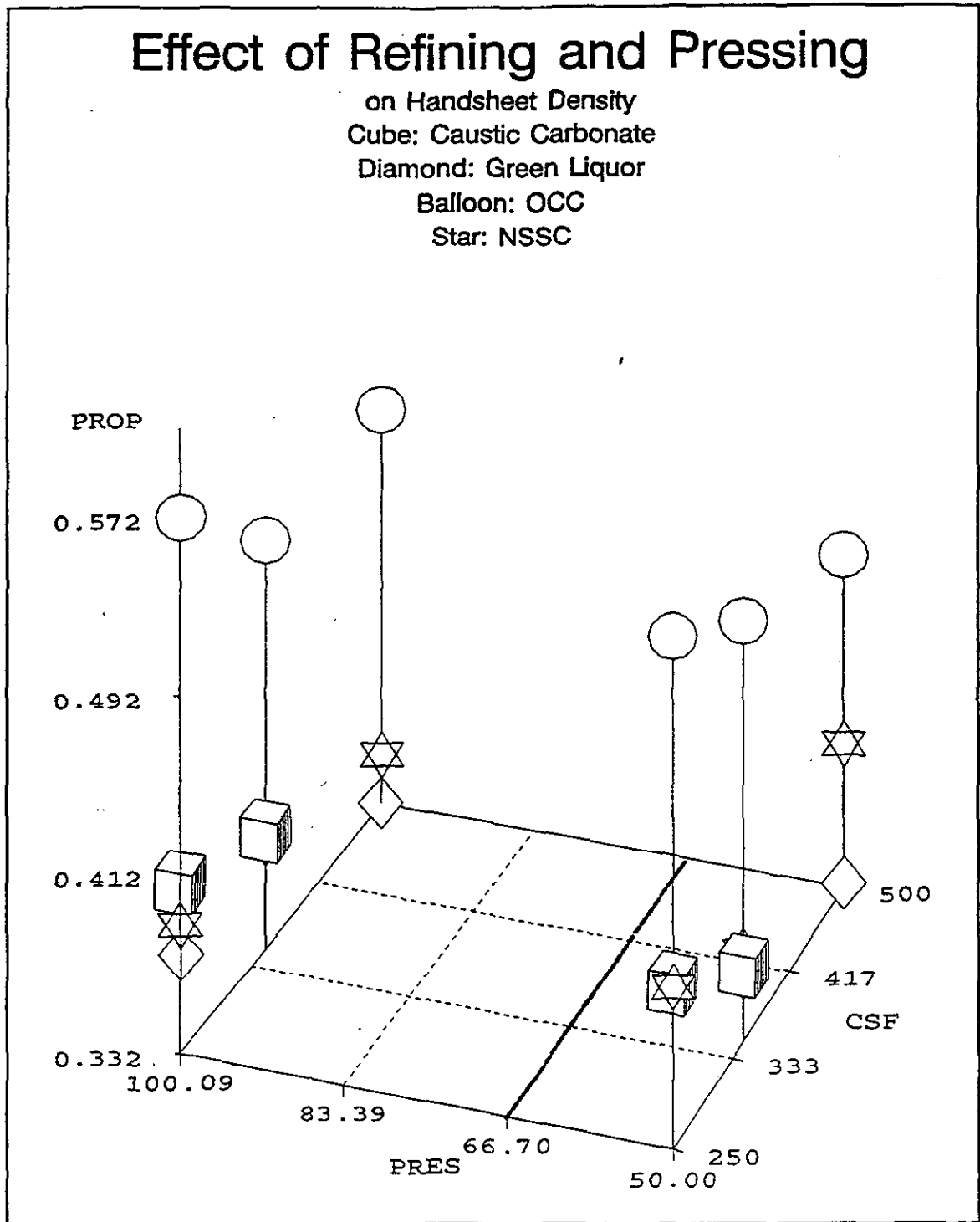


Figure 29

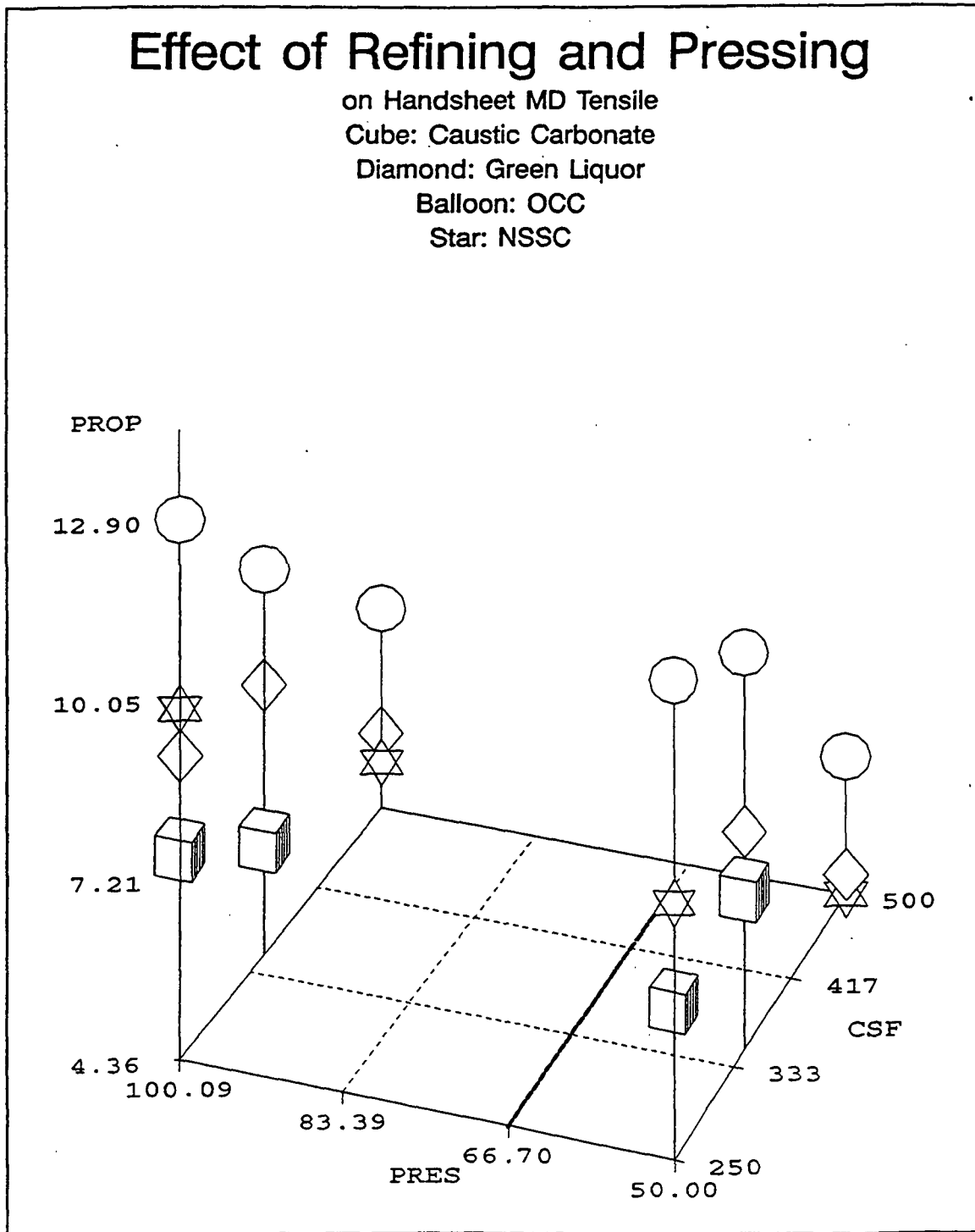


Figure 30

Effect of Refining and Pressing

on Handsheet CD Modulus

Cube: Caustic Carbonate

Diamond: Green Liquor

Balloon: OCC

Star: NSSC

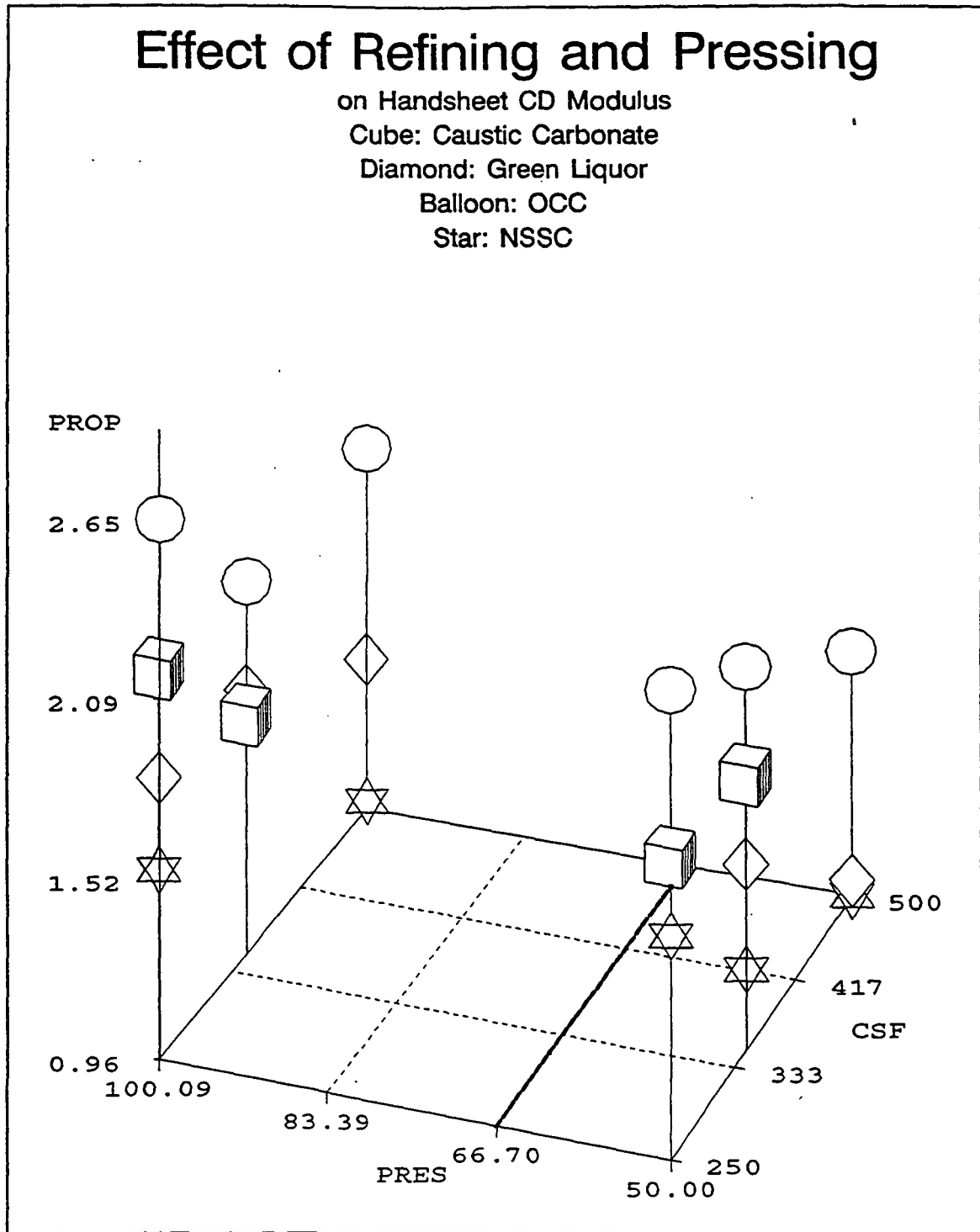


Figure 31

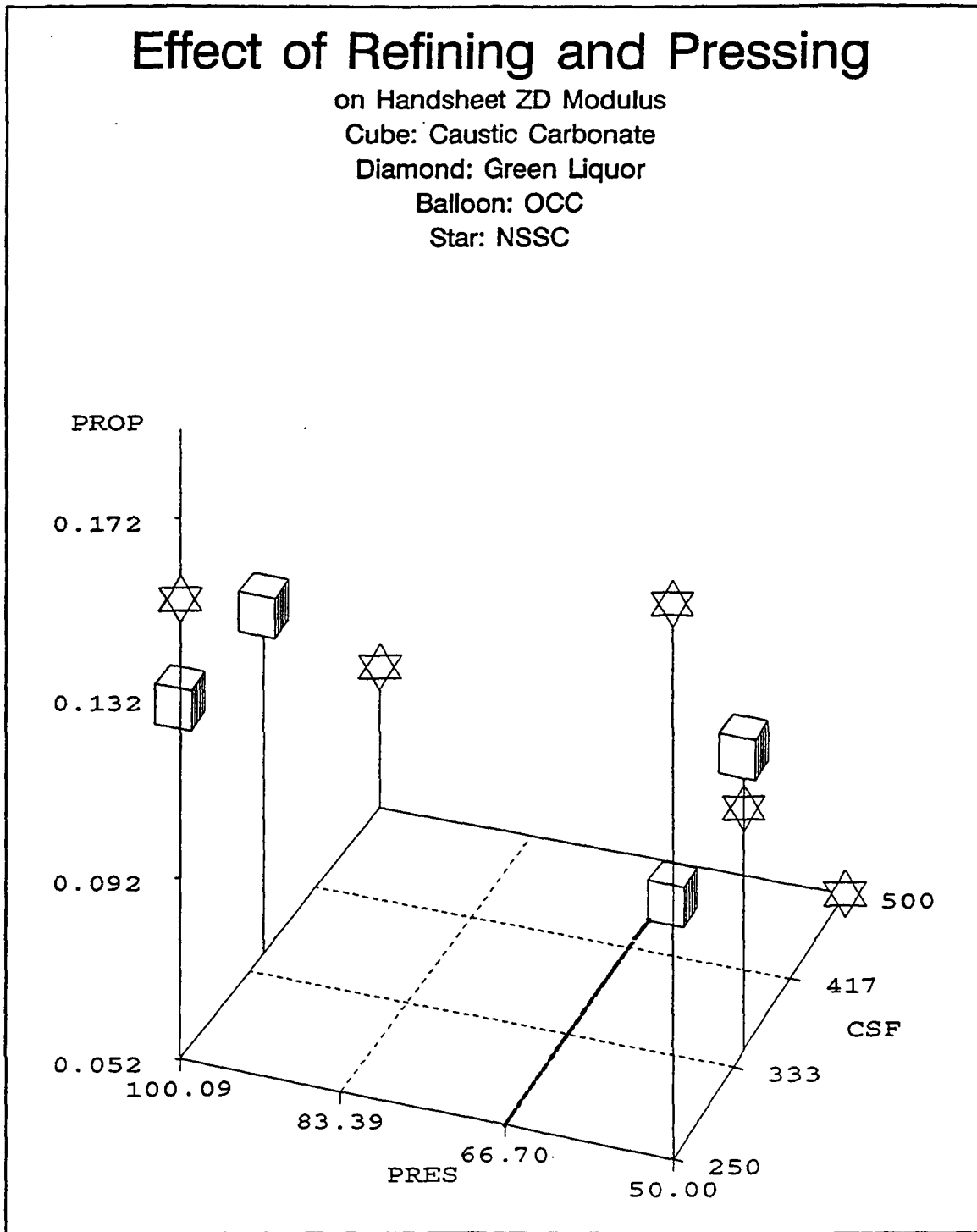
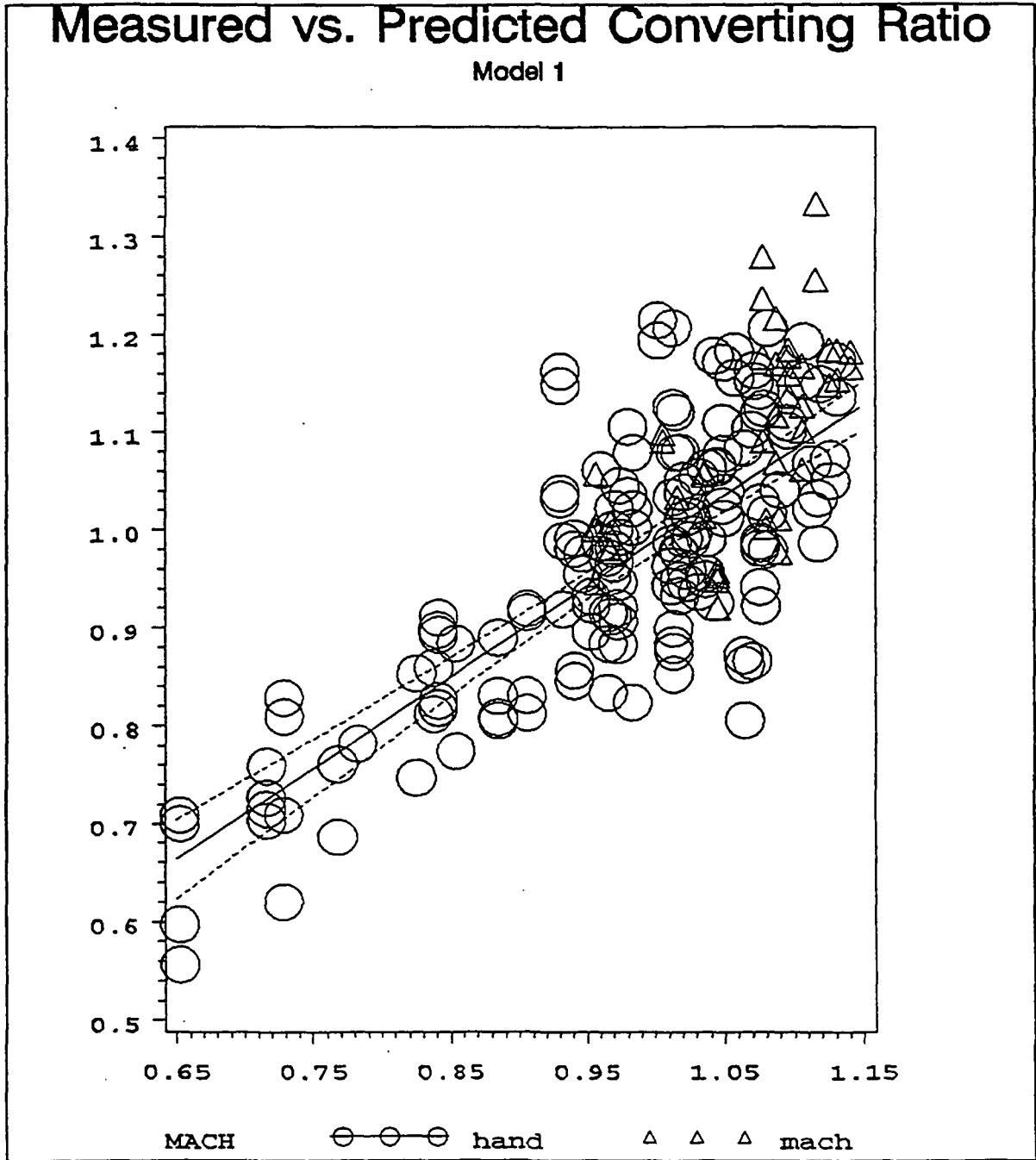


Figure 32



Gary Jones

Gary Jones

APPENDIX A

The orthotropic nature of paper results in variations in the elastic properties in the three principle directions within the sheet (in-plane MD and CD) and out-of-plane (ZD). The ultrasonic velocity method is an excellent non-intrusive method to determine the elastic properties in each of the principle directions for a variety of paper grades. These moduli can then be related to compressive properties and to bonding levels in the sheet.

Relationships have been developed between elastic properties and processing conditions such as refining and pressing and furnish characteristics. Thus the elastic properties can provide important diagnostic information on the effects of process and furnish on compressive strength.

The ultrasonic method relies on the transmission of high frequency sound waves through the sheet. The elastic stiffness is directly related to the speed of propagation of the wave. The device returns the velocity of sound, v , between two points. The device actually determines the time elapsed for the signal to reach the detector. Knowing the distance between the emitter and the detector and the time, it is possible to determine the velocity.

$$v = \frac{\text{caliper}}{\text{time}} \quad (4)$$

The specific modulus, \bar{E} , in the direction of the wave is equal to the square of the sonic velocity in that direction.

$$\bar{E} = v^2 \quad (5)$$

The method requires an accurate determination of the sheet caliper in order to determine the local density of the sheet. The local density is equal to the average basis weight divided by the local caliper.

$$\rho = \frac{BW}{\text{caliper}} \quad (6)$$

The modulus, E (GPa), is equal to the specific modulus multiplied by the sheet density.

$$E = \rho \bar{E} \quad (7)$$

The modulus expressed in terms of time, basis weight and caliper is then given by

$$E = \frac{\text{caliper} BW}{\text{time}^2} \quad (8)$$

Thus, it is essential to accurately determine the local sheet caliper. The current methods are all calibrated or designed for a perfectly flat surface. The typical wavelength is on the order of 5 cm. Thus the sonic waves are much longer than the typical waves of the flute. The current probes are not designed to measure elastic properties of fluted sheets. It isn't clear that ultrasonic technology could be developed to measure the in-plane properties of fluted medium because the geometry is so complex and non-planar. However, it may be possible to measure the transverse modulus at various locations along the flute using existing ultrasonic techniques. Strength loss has been shown to decrease with increasing transverse modulus.

APPENDIX B

Evaluation of Corrugating Mediums by the FLUTED EDGE CRUSH TEST

The Fluted Edge Crush Test was performed along the basic procedures as listed in the TAPPI Method T-824 with some major exceptions. The final test was run the same even though the modifications made to the test required that the fluted specimens be prepared in a different manner. The test method described below was developed by Carl Smith at the Institute.

TAPPI Method T-824 specifies a precut specimen, 0.500 inches CD by 6.00 inches MD. This specimen is then fluted in a Concora Medium Fluter, placed in the Stiffness Holder, and crush tested in 3 sec. or less. The method as modified and described in the following paragraphs basically takes a test sample from a corrugated unbonded medium sample that has been fluted in a conventional corrugator, and by means of a special sample cutter and test fixture can produce a test result similar to that described in T-824. The sample cutter and test fixture were modified to have the same flute profile as that used in the corrugator.

Preparation of the Unbonded Fluted Medium

Sample rolls of medium were corrugated on the IPST Single-Facer in the conventional manner. The adhesive application was modified so the center 6 inch portion of the adhesive roll used to apply the adhesive to the flute tips would be void of adhesive. A scraper was installed to physically remove any adhesive from the roll in this area at any time during the corrugating process. This resulted in single-face board with bonding only at the extreme outer edges of the flutes. At the same time the "scraper" was used, a crayon mark was made on the outside of the single-face liner to enable the operator to locate the unbonded samples at the termination of the corrugating run. Both machine paper (rolls as received from the mills) and handsheets (Formette sheets spliced into a roll large enough to be run on the corrugator) were corrugated with the unbonded areas present.

Several corrugating conditions were used in the fluting of the mediums on the corrugator. Not all conditions resulted in usable test sample. The higher corrugating speed in conjunction with reduced medium preconditioning tended to result in insufficient bonding and a loss of flute retention. The board produced must be fully bonded along either edge. If not, the flutes will try to flatten out. This will not allow the use of the special specimen cutting apparatus.

Modification of the H&D Test Fixture

The H&D Stiffness test fixture was modified to incorporate a new contoured clamping rack. This flute contour was designed to be the same contour as the C-flute rolls presently in the IPST Single-Facer.

In addition a similar set of fluted racks were made up to the same contour only of hardened steel and 0.500 inches wide by about 6 inches long. This was to be used for cutting and trimming the test specimen to the final size prior to testing.

Cutting and Testing the Fluted Medium

The samples of corrugated board were cut into pieces about 6 inches long in the MD. A sharp knife was used to cut away the unbonded section of the liner. The exposed corrugations were then clamped on either side by the fluted racks and placed in an alignment fixture.

Using a special support to allow the positioning of these 0.500 inch wide fluted racks, they were placed on either side of the fluted and unbonded medium so that a sharp blade could be used to trim all medium from the outside of the clamped area.

When cut to the test size, the specimen was removed from the fixture and placed immediately in the stiffness holder. A compression load was applied to the edges of the flutes and the failure load noted.

Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention

----- Forming Method=hand -----

OBS	Sample ID	Pulp Source	Handsheet CS Freeness	Handsheet Pressure	Corrugator Speed fpm	Corrugator Presteaming
1	4116-134	cc	350	low	500	no-steam
2	4116-134	cc	350	low	500	no-steam
3	4116-134	cc	350	low	500	no-steam
4	4116-134	cc	350	low	500	no-steam
5	4116-134	cc	350	low	500	steam
6	4116-134	cc	350	low	500	steam
7	4116-134	cc	350	low	800	steam
8	4116-134	cc	350	low	800	steam
9	4116-136	cc	350	hi	500	no-steam
10	4116-136	cc	350	hi	500	no-steam
11	4116-136	cc	350	hi	500	no-steam
12	4116-136	cc	350	hi	500	no-steam
13	4116-136	cc	350	hi	500	steam
14	4116-136	cc	350	hi	500	steam
15	4116-136	cc	350	hi	800	steam
16	4116-136	cc	350	hi	800	steam
17	4116-143	cc	250	low	500	no-steam
18	4116-143	cc	250	low	500	no-steam
19	4116-143	cc	250	low	500	no-steam
20	4116-143	cc	250	low	500	no-steam
21	4116-143	cc	250	low	500	steam
22	4116-143	cc	250	low	500	steam
23	4116-143	cc	250	low	800	steam
24	4116-143	cc	250	low	800	steam
25	4116-144	cc	250	hi	500	no-steam
26	4116-144	cc	250	hi	500	no-steam
27	4116-144	cc	250	hi	500	no-steam
28	4116-144	cc	250	hi	500	no-steam
29	4116-144	cc	250	hi	500	steam
30	4116-144	cc	250	hi	500	steam
31	4116-144	cc	250	hi	800	steam
32	4116-144	cc	250	hi	800	steam
33	4116-146	nssc	500	low	500	no-steam
34	4116-146	nssc	500	low	500	no-steam
35	4116-146	nssc	500	low	500	no-steam
36	4116-146	nssc	500	low	500	no-steam

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----

OBS	LUB	MD Hygro. at 75.5% RH	MD Hygro. at 93.4% RH	CD Hygro. at 75.5% RH	CD Hygro. at 93.4% RH
1	no-wax	0.175	0.357	0.275	0.618
2	no-wax	0.175	0.357	0.275	0.618
3	wax	0.175	0.357	0.275	0.618
4	wax	0.175	0.357	0.275	0.618
5	no-wax	0.175	0.357	0.275	0.618
6	no-wax	0.175	0.357	0.275	0.618
7	no-wax	0.175	0.357	0.275	0.618
8	no-wax	0.175	0.357	0.275	0.618
9	no-wax	.	.	.	.
10	no-wax	.	.	.	.
11	wax	.	.	.	.
12	wax	.	.	.	.
13	no-wax	.	.	.	.
14	no-wax	.	.	.	.
15	no-wax	.	.	.	.
16	no-wax	.	.	.	.
17	no-wax	0.166	0.349	0.283	0.635
18	no-wax	0.166	0.349	0.283	0.635
19	wax	0.166	0.349	0.283	0.635
20	wax	0.166	0.349	0.283	0.635
21	no-wax	0.166	0.349	0.283	0.635
22	no-wax	0.166	0.349	0.283	0.635
23	no-wax	0.166	0.349	0.283	0.635
24	no-wax	0.166	0.349	0.283	0.635
25	no-wax	.	.	.	.
26	no-wax	.	.	.	.
27	wax	.	.	.	.
28	wax	.	.	.	.
29	no-wax	.	.	.	.
30	no-wax	.	.	.	.
31	no-wax	.	.	.	.
32	no-wax	.	.	.	.
33	no-wax	.	.	.	.
34	no-wax	.	.	.	.
35	wax	.	.	.	.
36	wax	.	.	.	.

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----

OBS	Basis Weight g/m2	Caliper	Density g/cm3	MD Elastic Mod GPa	CD Elastic Mod GPa	ZD Elastic Mod GPa
1	131.3	359.6	0.3654	3.05	1.82	0.1190
2	131.3	359.6	0.3654	3.05	1.82	0.1190
3	131.3	359.6	0.3654	3.05	1.82	0.1190
4	131.3	359.6	0.3654	3.05	1.82	0.1190
5	131.3	359.6	0.3654	3.05	1.82	0.1190
6	131.3	359.6	0.3654	3.05	1.82	0.1190
7	131.3	359.6	0.3654	3.05	1.82	0.1190
8	131.3	359.6	0.3654	3.05	1.82	0.1190
9	133.5	346.6	0.3860	3.09	1.73	0.1315
10	133.5	346.6	0.3860	3.09	1.73	0.1315
11	133.5	346.6	0.3860	3.09	1.73	0.1315
12	133.5	346.6	0.3860	3.09	1.73	0.1315
13	133.5	346.6	0.3860	3.09	1.73	0.1315
14	133.5	346.6	0.3860	3.09	1.73	0.1315
15	133.5	346.6	0.3860	3.09	1.73	0.1315
16	133.5	346.6	0.3860	3.09	1.73	0.1315
17	137.0	338.5	0.4043	3.47	1.88	0.1090
18	137.0	338.5	0.4043	3.47	1.88	0.1090
19	137.0	338.5	0.4043	3.47	1.88	0.1090
20	137.0	338.5	0.4043	3.47	1.88	0.1090
21	137.0	338.5	0.4043	3.47	1.88	0.1090
22	137.0	338.5	0.4043	3.47	1.88	0.1090
23	137.0	338.5	0.4043	3.47	1.88	0.1090
24	137.0	338.5	0.4043	3.47	1.88	0.1090
25	136.0	333.5	0.4078	3.61	2.18	0.1320
26	136.0	333.5	0.4078	3.61	2.18	0.1320
27	136.0	333.5	0.4078	3.61	2.18	0.1320
28	136.0	333.5	0.4078	3.61	2.18	0.1320
29	136.0	333.5	0.4078	3.61	2.18	0.1320
30	136.0	333.5	0.4078	3.61	2.18	0.1320
31	136.0	333.5	0.4078	3.61	2.18	0.1320
32	136.0	333.5	0.4078	3.61	2.18	0.1320
33	138.6	365.7	0.3992	3.39	0.96	0.0520
34	138.6	365.7	0.3992	3.39	0.96	0.0520
35	138.6	365.7	0.3992	3.39	0.96	0.0520
36	138.6	365.7	0.3992	3.39	0.96	0.0520

Project Database
Handsheets Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
(continued)

OBS	Shear Modulus GPa	Poisson Ratio CD/MD	MD Ring Crush lb/6 in	CD Ring Crush lb/6 in	MD STFI lb/6 in.	CD STFI lb/6 in.
1	0.900	0.355	60.00	49.2	.	.
2	0.900	0.355	60.00	49.2	.	.
3	0.900	0.355	60.00	49.2	.	.
4	0.900	0.355	60.00	49.2	.	.
5	0.900	0.355	60.00	49.2	.	.
6	0.900	0.355	60.00	49.2	.	.
7	0.900	0.355	60.00	49.2	.	.
8	0.900	0.355	60.00	49.2	.	.
9	0.885	0.355	.	.	.	.
10	0.885	0.355	59.85	49.6	.	.
11	0.885	0.355	59.85	49.6	.	.
12	0.885	0.355	59.85	49.6	.	.
13	0.885	0.355	.	.	.	.
14	0.885	0.355	59.85	49.6	.	.
15	0.885	0.355	.	.	.	.
16	0.885	0.355	59.85	49.6	.	.
17	0.960	0.380	66.90	53.3	.	.
18	0.960	0.380	66.90	53.3	.	.
19	0.960	0.380	66.90	53.3	.	.
20	0.960	0.380	66.90	53.3	.	.
21	0.960	0.380	66.90	53.3	.	.
22	0.960	0.380	66.90	53.3	.	.
23	0.960	0.380	66.90	53.3	.	.
24	0.960	0.380	66.90	53.3	.	.
25	1.080	0.345	63.45	53.8	.	.
26	1.080	0.345	63.45	53.8	.	.
27	1.080	0.345	63.45	53.8	.	.
28	1.080	0.345	63.45	53.8	.	.
29	1.080	0.345	63.45	53.8	.	.
30	1.080	0.345	63.45	53.8	.	.
31	1.080	0.345	63.45	53.8	.	.
32	1.080	0.345	63.45	53.8	.	.
33	0.620	0.490	41.40	29.3	.	.
34	0.620	0.490	41.40	29.3	.	.
35	0.620	0.490	41.40	29.3	.	.
36	0.620	0.490	41.40	29.3	.	.

Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Fluted Edge Crush lb/6 in.	Ratio of Fluted Edge Crush to CD RC	Model 1	
			Pred. Ratio of Edge Crush	Ratio of Fluted Edge Crush
1	43.46	0.88	0.95	.
2	41.02	0.83	0.95	.
3	47.80	0.97	0.95	.
4	45.00	0.91	0.95	.
5	49.90	1.01	1.02	.
6	48.70	0.99	1.02	.
7	47.00	0.96	1.02	.
8	46.70	0.95	1.02	.
9	43.50	.	0.93	.
10	44.41	0.90	0.93	.
11	46.20	0.93	0.93	.
12	45.80	0.92	0.93	.
13	46.80	.	1.00	.
14	48.50	0.98	1.00	.
15	50.40	.	1.00	.
16	49.40	1.00	1.00	.
17	47.02	0.88	0.96	.
18	49.04	0.92	0.96	.
19	48.30	0.91	0.96	.
20	50.42	0.95	0.96	.
21	49.90	0.94	1.02	.
22	56.20	1.05	1.02	.
23	49.30	0.92	1.02	.
24	62.80	1.18	1.02	.
25	56.51	1.05	1.02	.
26	55.87	1.04	1.02	.
27	54.40	1.01	1.02	.
28	53.30	0.99	1.02	.
29	62.60	1.16	1.07	.
30	62.00	1.15	1.07	.
31	52.70	0.98	1.07	.
32	64.90	1.21	1.07	.
33	20.77	0.71	0.63	.
34	20.51	0.70	0.63	.
35	17.50	0.60	0.63	.
36	16.30	0.56	0.63	.

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
(continued)

OBS	MD Tensile	CD Tensile	MD TEA	CD TEA
1	6.8700	0.7754	78.20	11.600
2	6.8700	0.7754	78.20	11.600
3	6.8700	0.7754	78.20	11.600
4	6.8700	0.7754	78.20	11.600
5	6.8700	0.7754	78.20	11.600
6	6.8700	0.7754	78.20	11.600
7	6.8700	0.7754	78.20	11.600
8	6.8700	0.7754	78.20	11.600
9	6.2050	0.6863	70.79	10.280
10	6.2050	0.6863	70.79	10.280
11	6.2050	0.6863	70.79	10.280
12	6.2050	0.6863	70.79	10.280
13	6.2050	0.6863	70.79	10.280
14	6.2050	0.6863	70.79	10.280
15	6.2050	0.6863	70.79	10.280
16	6.2050	0.6863	70.79	10.280
17	6.7800	0.7189	68.44	10.205
18	6.7800	0.7189	68.44	10.205
19	6.7800	0.7189	68.44	10.205
20	6.7800	0.7189	68.44	10.205
21	6.7800	0.7189	68.44	10.205
22	6.7800	0.7189	68.44	10.205
23	6.7800	0.7189	68.44	10.205
24	6.7800	0.7189	68.44	10.205
25	7.6630	0.8455	97.92	12.310
26	7.6630	0.8455	97.92	12.310
27	7.6630	0.8455	97.92	12.310
28	7.6630	0.8455	97.92	12.310
29	7.6630	0.8455	97.92	12.310
30	7.6630	0.8455	97.92	12.310
31	7.6630	0.8455	97.92	12.310
32	7.6630	0.8455	97.92	12.310
33	4.3620	0.3440	21.44	4.080
34	4.3620	0.3440	21.44	4.080
35	4.3620	0.3440	21.44	4.080
36	4.3620	0.3440	21.44	4.080

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Sample ID	Pulp Source	Handsheet CS Freeness	Handsheet Pressure	Corrugator Speed fpm	Corrugator Presteaming
37	4116-146	nssc	500	low	500	steam
38	4116-146	nssc	500	low	500	steam
39	4116-146	nssc	500	low	800	steam
40	4116-146	nssc	500	low	800	steam
41	4116-148	nssc	500	hi	500	no-steam
42	4116-148	nssc	500	hi	500	no-steam
43	4116-148	nssc	500	hi	500	steam
44	4116-148	nssc	500	hi	500	steam
45	4116-148	nssc	500	hi	500	no-steam
46	4116-148	nssc	500	hi	500	no-steam
47	4116-148	nssc	500	hi	800	steam
48	4116-148	nssc	500	hi	800	steam
49	4116-149	nssc	250	low	500	no-steam
50	4116-149	nssc	250	low	500	no-steam
51	4116-149	nssc	250	low	500	no-steam
52	4116-149	nssc	250	low	500	no-steam
53	4116-149	nssc	250	low	500	steam
54	4116-149	nssc	250	low	500	steam
55	4116-149	nssc	250	low	800	steam
56	4116-149	nssc	250	low	800	steam
57	4116-150	nssc	250	hi	500	no-steam
58	4116-150	nssc	250	hi	500	no-steam
59	4116-150	nssc	250	hi	500	no-steam
60	4116-150	nssc	250	hi	500	no-steam
61	4116-150	nssc	250	hi	500	steam
62	4116-150	nssc	250	hi	500	steam
63	4116-150	nssc	250	hi	800	steam
64	4116-150	nssc	250	hi	800	steam
65	4116-152	nssc	350	low	500	no-steam
66	4116-152	nssc	350	low	500	no-steam
67	4116-152	nssc	350	low	500	no-steam
68	4116-152	nssc	350	low	500	no-steam
69	4116-152	nssc	350	low	500	steam
70	4116-152	nssc	350	low	500	steam
71	4116-152	nssc	350	low	800	steam
72	4116-152	nssc	350	low	800	steam

**Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention**

----- Forming* Method=hand -----
(continued)

OBS	LUB	MD Hygro. at 75.5% RH	MD Hygro. at 93.4% RH	CD Hygro. at 75.5% RH	CD Hygro. at 93.4% RH
37	no-wax	.	.	.	.
38	no-wax	.	.	.	.
39	no-wax	.	.	.	.
40	no-wax	.	.	.	.
41	no-wax	.	.	.	.
42	no-wax	.	.	.	.
43	no-wax	.	.	.	.
44	no-wax	.	.	.	.
45	wax	.	.	.	.
46	wax	.	.	.	.
47	no-wax	.	.	.	.
48	no-wax	.	.	.	.
49	no-wax	0.196	0.391	0.511	1.066
50	no-wax	0.196	0.391	0.511	1.066
51	wax	0.196	0.391	0.511	1.066
52	wax	0.196	0.391	0.511	1.066
53	no-wax	0.196	0.391	0.511	1.066
54	no-wax	0.196	0.391	0.511	1.066
55	no-wax	0.196	0.391	0.511	1.066
56	no-wax	0.196	0.391	0.511	1.066
57	no-wax	.	.	.	.
58	no-wax	.	.	.	.
59	wax	.	.	.	.
60	wax	.	.	.	.
61	no-wax	.	.	.	.
62	no-wax	.	.	.	.
63	no-wax	.	.	.	.
64	no-wax	.	.	.	.
65	no-wax	0.189	0.355	0.385	0.832
66	no-wax	0.189	0.355	0.385	0.832
67	wax	0.189	0.355	0.385	0.832
68	wax	0.189	0.355	0.385	0.832
69	no-wax	0.189	0.355	0.385	0.832
70	no-wax	0.189	0.355	0.385	0.832
71	no-wax	0.189	0.355	0.385	0.832
72	no-wax	0.189	0.355	0.385	0.832

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Basis Weight g/m2	Caliper	Density g/cm3	MD Elastic Mod GPa	CD Elastic Mod GPa	ZD Elastic Mod GPa
37	138.60	365.7	0.3992	3.39	0.960	0.0520
38	138.60	365.7	0.3992	3.39	0.960	0.0520
39	138.60	365.7	0.3992	3.39	0.960	0.0520
40	138.60	365.7	0.3992	3.39	0.960	0.0520
41	136.45	384.0	0.3550	3.59	0.985	0.0855
42	136.45	384.0	0.3550	3.59	0.985	0.0855
43	136.45	384.0	0.3550	3.59	0.985	0.0855
44	136.45	384.0	0.3550	3.59	0.985	0.0855
45	136.45	384.0	0.3550	3.59	0.985	0.0855
46	136.45	384.0	0.3550	3.59	0.985	0.0855
47	136.45	384.0	0.3550	3.59	0.985	0.0855
48	136.45	384.0	0.3550	3.59	0.985	0.0855
49	137.20	339.6	0.4028	4.53	1.640	0.1720
50	137.20	339.6	0.4028	4.53	1.640	0.1720
51	137.20	339.6	0.4028	4.53	1.640	0.1720
52	137.20	339.6	0.4028	4.53	1.640	0.1720
53	137.20	339.6	0.4028	4.53	1.640	0.1720
54	137.20	339.6	0.4028	4.53	1.640	0.1720
55	137.20	339.6	0.4028	4.53	1.640	0.1720
56	137.20	339.6	0.4028	4.53	1.640	0.1720
57	143.80	378.8	0.3893	3.89	1.550	0.1540
58	143.80	378.8	0.3893	3.89	1.550	0.1540
59	143.80	378.8	0.3893	3.89	1.550	0.1540
60	143.80	378.8	0.3893	3.89	1.550	0.1540
61	143.80	378.8	0.3893	3.89	1.550	0.1540
62	143.80	378.8	0.3893	3.89	1.550	0.1540
63	143.80	378.8	0.3893	3.89	1.550	0.1540
64	143.80	378.8	0.3893	3.89	1.550	0.1540
65	134.10	360.1	0.3720	4.04	1.210	0.1055
66	134.10	360.1	0.3720	4.04	1.210	0.1055
67	134.10	360.1	0.3720	4.04	1.210	0.1055
68	134.10	360.1	0.3720	4.04	1.210	0.1055
69	134.10	360.1	0.3720	4.04	1.210	0.1055
70	134.10	360.1	0.3720	4.04	1.210	0.1055
71	134.10	360.1	0.3720	4.04	1.210	0.1055
72	134.10	360.1	0.3720	4.04	1.210	0.1055

Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Shear Modulus GPa	Poisson Ratio CD/MD	MD Ring Crush lb/6 in	CD Ring Crush lb/6 in	MD STFI lb/6 in.	CD STFI lb/6 in.
37	0.620	0.49	41.40	29.30	.	.
38	0.620	0.49	41.40	29.30	.	.
39	0.620	0.49	41.40	29.30	.	.
40	0.620	0.49	41.40	29.30	.	.
41	0.645	0.46	52.05	29.20	.	.
42	0.645	0.46	52.05	29.20	.	.
43	0.645	0.46	52.05	29.20	.	.
44	0.645	0.46	52.05	29.20	.	.
45	0.645	0.46	52.05	29.20	.	.
46	0.645	0.46	52.05	29.20	.	.
47	0.645	0.46	52.05	29.20	.	.
48	0.645	0.46	52.05	29.20	.	.
49	0.975	0.43	70.45	47.95	.	.
50	0.975	0.43	70.45	47.95	.	.
51	0.975	0.43	70.45	47.95	.	.
52	0.975	0.43	70.45	47.95	.	.
53	0.975	0.43	70.45	47.95	.	.
54	0.975	0.43	70.45	47.95	.	.
55	0.975	0.43	70.45	47.95	.	.
56	0.975	0.43	70.45	47.95	.	.
57	0.903	0.39	68.70	57.00	.	.
58	0.903	0.39	68.70	57.00	.	.
59	0.903	0.39	68.70	57.00	.	.
60	0.903	0.39	68.70	57.00	.	.
61	0.903	0.39	68.70	57.00	.	.
62	0.903	0.39	68.70	57.00	.	.
63	0.903	0.39	68.70	57.00	.	.
64	0.903	0.39	68.70	57.00	.	.
65	0.760	0.50	58.95	38.65	.	.
66	0.760	0.50	58.95	38.65	.	.
67	0.760	0.50	58.95	38.65	.	.
68	0.760	0.50	58.95	38.65	.	.
69	0.760	0.50	58.95	38.65	.	.
70	0.760	0.50	58.95	38.65	.	.
71	0.760	0.50	58.95	38.65	.	.
72	0.760	0.50	58.95	38.65	.	.

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Fluted Edge Crush lb/6 in.	Ratio of Fluted Edge Crush to CD RC	Model 1 Pred. Ratio of Edge Crush to CD RC	Ratio of Fluted Edge Crush to CD STFI
37	22.30	0.76	0.75	.
38	20.10	0.69	0.75	.
39	22.90	0.78	0.75	.
40	22.90	0.78	0.75	.
41	24.19	0.83	0.75	.
42	23.63	0.81	0.75	.
43	26.20	0.90	0.87	.
44	23.90	0.82	0.87	.
45	20.70	0.71	0.75	.
46	18.10	0.62	0.75	.
47	25.80	0.88	0.87	.
48	22.60	0.77	0.87	.
49	49.00	1.02	0.97	.
50	47.02	0.98	0.97	.
51	46.30	0.97	0.97	.
52	48.00	1.00	0.97	.
53	51.00	1.06	1.05	.
54	47.50	0.99	1.05	.
55	49.80	1.04	1.05	.
56	48.50	1.01	1.05	.
57	56.51	0.99	0.95	.
58	55.87	0.98	0.95	.
59	48.20	0.85	0.95	.
60	48.80	0.86	0.95	.
61	53.70	0.94	1.03	.
62	54.90	0.96	1.03	.
63	53.90	0.95	1.03	.
64	54.60	0.96	1.03	.
65	35.17	0.91	0.83	.
66	34.50	0.89	0.83	.
67	31.90	0.83	0.83	.
68	31.60	0.82	0.83	.
69	38.20	0.99	0.93	.
70	35.50	0.92	0.93	.
71	36.90	0.95	0.93	.
72	37.70	0.98	0.93	.

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	MD Tensile	CD Tensile	MD TEA	CD TEA
37	4.3620	0.344	21.440	4.080
38	4.3620	0.344	21.440	4.080
39	4.3620	0.344	21.440	4.080
40	4.3620	0.344	21.440	4.080
41	5.1355	0.391	23.765	4.801
42	5.1355	0.391	23.765	4.801
43	5.1355	0.391	23.765	4.801
44	5.1355	0.391	23.765	4.801
45	5.1355	0.391	23.765	4.801
46	5.1355	0.391	23.765	4.801
47	5.1355	0.391	23.765	4.801
48	5.1355	0.391	23.765	4.801
49	8.2910	2.831	79.930	35.780
50	8.2910	2.831	79.930	35.780
51	8.2910	2.831	79.930	35.780
52	8.2910	2.831	79.930	35.780
53	8.2910	2.831	79.930	35.780
54	8.2910	2.831	79.930	35.780
55	8.2910	2.831	79.930	35.780
56	8.2910	2.831	79.930	35.780
57	9.8950	2.727	107.350	20.520
58	9.8950	2.727	107.350	20.520
59	9.8950	2.727	107.350	20.520
60	9.8950	2.727	107.350	20.520
61	9.8950	2.727	107.350	20.520
62	9.8950	2.727	107.350	20.520
63	9.8950	2.727	107.350	20.520
64	9.8950	2.727	107.350	20.520
65	6.8375	2.320	51.610	34.600
66	6.8375	2.320	51.610	34.600
67	6.8375	2.320	51.610	34.600
68	6.8375	2.320	51.610	34.600
69	6.8375	2.320	51.610	34.600
70	6.8375	2.320	51.610	34.600
71	6.8375	2.320	51.610	34.600
72	6.8375	2.320	51.610	34.600

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

DBS	Sample ID	Pulp Source	Handsheet		Corrugator	Corrugator Presteaming	
			CS	Freeness	Pressure		Speed fpm
73	4116-153	nssc		350	hi	500	no-steam
74	4116-153	nssc		350	hi	500	no-steam
75	4116-153	nssc		350	hi	500	no-steam
76	4116-153	nssc		350	hi	500	steam
77	4116-153	nssc		350	hi	500	steam
78	4116-153	nssc		350	hi	800	steam
79	4116-153	nssc		350	hi	800	steam
80	4116-155	occ		500	low	500	no-steam
81	4116-155	occ		500	low	500	no-steam
82	4116-155	occ		500	low	500	no-steam
83	4116-155	occ		500	low	500	no-steam
84	4116-155	occ		500	low	500	steam
85	4116-155	occ		500	low	500	steam
86	4116-155	occ		500	low	800	steam
87	4116-155	occ		500	low	800	steam
88	4116-156	occ		500	hi	500	no-steam
89	4116-156	occ		500	hi	500	no-steam
90	4116-156	occ		500	hi	500	no-steam
91	4116-156	occ		500	hi	500	no-steam
92	4116-156	occ		500	hi	500	steam
93	4116-156	occ		500	hi	500	steam
94	4116-156	occ		500	hi	800	steam
95	4116-156	occ		500	hi	800	steam
96	4116-158	occ		350	low	500	no-steam
97	4116-158	occ		350	low	500	no-steam
98	4116-158	occ		350	low	500	no-steam
99	4116-158	occ		350	low	500	no-steam
100	4116-158	occ		350	low	500	steam
101	4116-158	occ		350	low	500	steam
102	4116-158	occ		350	low	800	steam
103	4116-158	occ		350	low	800	steam
104	4116-160	occ		350	hi	500	no-steam
105	4116-160	occ		350	hi	500	no-steam
106	4116-160	occ		350	hi	500	no-steam
107	4116-160	occ		350	hi	500	no-steam
108	4116-160	occ		350	hi	500	steam

Project Database
Handsheets Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	LUB	MD Hygro. at 75.5% RH	MD Hygro. at 93.4% RH	CD Hygro. at 75.5% RH	CD Hygro. at 93.4% RH
73	no-wax	.	.	.	.
74	wax	.	.	.	.
75	wax	.	.	.	.
76	no-wax	.	.	.	.
77	no-wax	.	.	.	.
78	no-wax	.	.	.	.
79	no-wax	.	.	.	.
80	no-wax	0.176	0.382	0.310	0.708
81	no-wax	0.176	0.382	0.310	0.708
82	wax	0.176	0.382	0.310	0.708
83	wax	0.176	0.382	0.310	0.708
84	no-wax	0.176	0.382	0.310	0.708
85	no-wax	0.176	0.382	0.310	0.708
86	no-wax	0.176	0.382	0.310	0.708
87	no-wax	0.176	0.382	0.310	0.708
88	no-wax	0.169	0.365	0.235	0.539
89	no-wax	0.169	0.365	0.235	0.539
90	wax	0.169	0.365	0.235	0.539
91	wax	0.169	0.365	0.235	0.539
92	no-wax	0.169	0.365	0.235	0.539
93	no-wax	0.169	0.365	0.235	0.539
94	no-wax	0.169	0.365	0.235	0.539
95	no-wax	0.169	0.365	0.235	0.539
96	no-wax	0.143	0.287	0.268	0.590
97	no-wax	0.143	0.287	0.268	0.590
98	wax	0.143	0.287	0.268	0.590
99	wax	0.143	0.287	0.268	0.590
100	no-wax	0.143	0.287	0.268	0.590
101	no-wax	0.143	0.287	0.268	0.590
102	no-wax	0.143	0.287	0.268	0.590
103	no-wax	0.143	0.287	0.268	0.590
104	no-wax	0.140	0.287	0.292	0.675
105	no-wax	0.140	0.287	0.292	0.675
106	wax	0.140	0.287	0.292	0.675
107	wax	0.140	0.287	0.292	0.675
108	no-wax	0.140	0.287	0.292	0.675

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Basis Weight g/m ²	Caliper	Density g/cm ³	MD Elastic Mod GPa	CD Elastic Mod GPa	ZD Elastic Mod GPa
73	129.90	197.50	0.6580	7.43	2.55	0.1700
74	.	.	.	7.43	2.55	0.1700
75	129.90	197.50	0.6580	7.43	2.55	0.1700
76	129.90	197.50	0.6580	7.43	2.55	0.1700
77	129.90	197.50	0.6580	7.43	2.55	0.1700
78	129.90	197.50	0.6580	7.43	2.55	0.1700
79	129.90	197.50	0.6580	7.43	2.55	0.1700
80	121.50	248.90	0.4880	4.82	1.76	0.0570
81	121.50	248.90	0.4880	4.82	1.76	0.0570
82	121.50	248.90	0.4880	4.82	1.76	0.0570
83	121.50	248.90	0.4880	4.82	1.76	0.0570
84	121.50	248.90	0.4880	4.82	1.76	0.0570
85	121.50	248.90	0.4880	4.82	1.76	0.0570
86	121.50	248.90	0.4880	4.82	1.76	0.0570
87	121.50	248.90	0.4880	4.82	1.76	0.0570
88	126.00	242.00	0.5210	5.92	2.17	0.0990
89	126.00	242.00	0.5210	5.92	2.17	0.0990
90	126.00	242.00	0.5210	5.92	2.17	0.0990
91	126.00	242.00	0.5210	5.92	2.17	0.0990
92	126.00	242.00	0.5210	5.92	2.17	0.0990
93	126.00	242.00	0.5210	5.92	2.17	0.0990
94	126.00	242.00	0.5210	5.92	2.17	0.0990
95	126.00	242.00	0.5210	5.92	2.17	0.0990
96	130.35	250.50	0.5205	6.52	2.16	0.1025
97	130.35	250.50	0.5205	6.52	2.16	0.1025
98	130.35	250.50	0.5205	6.52	2.16	0.1025
99	130.35	250.50	0.5205	6.52	2.16	0.1025
100	130.35	250.50	0.5205	6.52	2.16	0.1205
101	130.35	250.50	0.5205	6.52	2.16	0.1025
102	130.35	250.50	0.5205	6.52	2.16	0.1025
103	130.35	250.50	0.5205	6.52	2.16	0.1205
104	130.35	250.55	0.5205	6.52	2.16	0.0940
105	130.35	250.55	0.5205	6.52	2.16	0.0940
106	130.35	250.55	0.5205	6.52	2.16	0.0940
107	130.35	250.55	0.5205	6.52	2.16	0.0940
108	130.35	250.55	0.5205	6.52	2.16	0.0940

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Shear Modulus GPa	Poisson Ratio CD/MD	MD Ring Crush lb/6 in	CD Ring Crush lb/6 in	MD STFI lb/6 in.	CD STFI lb/6 in.
73	1.55	0.440	61.98	44.00	29.14	13.86
74	1.55	0.440	61.98	44.00	29.14	13.86
75	1.55	0.440	61.98	44.00	29.14	13.86
76	1.55	0.440	61.98	44.00	29.14	13.86
77	1.55	0.440	61.98	44.00	29.14	13.86
78	1.55	0.440	61.98	44.00	29.14	13.86
79	1.55	0.440	61.98	44.00	29.14	13.86
80	1.07	0.393	35.91	26.77	18.46	8.61
81	1.07	0.393	35.91	26.77	18.46	8.61
82	1.07	0.393	35.91	26.77	18.46	8.61
83	1.07	0.393	35.91	26.77	18.46	8.61
84	1.07	0.393	35.91	26.77	18.46	8.61
85	1.07	0.393	35.91	26.77	18.46	8.61
86	1.07	0.393	35.91	26.77	18.46	8.61
87	1.07	0.393	35.91	26.77	18.46	8.61
88	1.31	0.403	42.10	30.04	21.29	10.00
89	1.31	0.403	42.10	30.04	21.29	10.00
90	1.31	0.403	42.10	30.04	21.29	10.00
91	1.31	0.403	42.10	30.04	21.29	10.00
92	1.31	0.403	42.10	30.04	21.29	10.00
93	1.31	0.403	42.10	30.04	21.29	10.00
94	1.31	0.403	42.10	30.04	21.29	10.00
95	1.31	0.403	42.10	30.04	21.29	10.00
96	1.35	0.405	53.87	36.90	25.95	11.12
97	1.35	0.405	53.87	36.90	25.95	11.12
98	1.35	0.405	53.87	36.90	25.95	11.12
99	1.35	0.405	53.87	36.90	25.95	11.12
100	1.35	0.405	53.87	36.90	25.95	11.12
101	1.35	0.405	53.87	36.90	25.95	11.12
102	1.35	0.405	53.87	36.90	25.95	11.12
103	1.35	0.405	53.87	36.90	25.95	11.12
104	1.35	0.405	53.11	35.80	24.18	11.23
105	1.35	0.405	53.11	35.80	24.18	11.23
106	1.35	0.405	53.11	35.80	24.18	11.23
107	1.35	0.405	53.11	35.80	24.18	11.23
108	1.35	0.405	53.11	35.80	24.18	11.23

Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Fluted Edge Crush lb/6 in.	Ratio of Fluted Edge Crush to CD RC	Model 1 Pred. Ratio of Edge Crush to CD RC	Ratio of Fluted Edge Crush to CD STFI
73	.	.	1.04	.
74	39.50	0.90	.	2.85
75	38.10	0.87	1.04	2.75
76	47.00	1.07	1.08	3.39
77	44.90	1.02	1.08	3.24
78	46.20	1.05	1.08	3.33
79	47.20	1.07	1.08	3.41
80	21.76	0.81	0.91	2.53
81	22.24	0.83	0.91	2.58
82	24.60	0.92	0.91	2.86
83	24.50	0.92	0.91	2.85
84	24.40	0.91	0.98	2.83
85	25.50	0.95	0.98	2.96
86	29.60	1.11	0.98	3.44
87	27.70	1.03	0.98	3.22
88	26.50	0.88	1.02	2.65
89	26.30	0.88	1.02	2.63
90	25.60	0.85	1.02	2.56
91	27.00	0.90	1.02	2.70
92	25.90	0.86	1.07	2.59
93	24.20	0.81	1.07	2.42
94	29.60	0.99	1.07	2.96
95	27.70	0.92	1.07	2.77
96	34.40	0.93	1.03	3.09
97	36.04	0.98	1.03	3.24
98	35.00	0.95	1.03	3.15
99	39.84	1.08	1.03	3.58
100	41.50	1.12	1.09	3.73
101	40.70	1.10	1.09	3.66
102	37.50	1.02	1.09	3.37
103	38.40	1.04	1.09	3.45
104	40.30	1.13	1.03	3.59
105	43.20	1.21	1.03	3.85
106	37.00	1.03	1.03	3.29
107	35.30	0.99	1.03	3.14
108	38.80	1.08	1.08	3.46

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	MD Tensile	CD Tensile	MD TEA	CD TEA
73	.	.	.	.
74	.	.	.	.
75	.	.	.	.
76	.	.	.	.
77	.	.	.	.
78	.	.	.	.
79	.	.	.	.
80	6.639	2.304	92.89	52.245
81	6.639	2.304	92.89	52.245
82	6.639	2.304	92.89	52.245
83	6.639	2.304	92.89	52.245
84	6.639	2.304	92.89	52.245
85	6.639	2.304	92.89	52.245
86	6.639	2.304	92.89	52.245
87	6.639	2.304	92.89	52.245
88	7.750	2.643	106.00	67.070
89	7.750	2.643	106.00	67.070
90	7.750	2.643	106.00	67.070
91	7.750	2.643	106.00	67.070
92	7.750	2.643	106.00	67.070
93	7.750	2.643	106.00	67.070
94	7.750	2.643	106.00	67.070
95	7.750	2.643	106.00	67.070
96	10.630	3.100	158.50	68.080
97	10.630	3.100	158.50	68.080
98	10.630	3.100	158.50	68.080
99	10.630	3.100	158.50	68.080
100	10.630	3.100	158.50	68.080
101	10.630	3.100	158.50	68.080
102	10.630	3.100	158.50	68.080
103	10.630	3.100	158.50	68.080
104	10.630	3.097	158.50	68.080
105	10.630	3.097	158.50	68.080
106	10.630	3.097	158.50	68.080
107	10.630	3.097	158.50	68.080
108	10.630	3.097	158.50	68.080

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Sample ID	Pulp Source	Handsheet CS Freeness	Handsheet Pressure	Corrugator Speed fpm	Corrugator Presteaming
109	4116-160	occ	350	hi	500	steam
110	4116-160	occ	350	hi	800	steam
111	4116-160	occ	350	hi	800	steam
112	4116-161	occ	250	lo	500	no-steam
113	4116-161	occ	250	lo	500	no-steam
114	4116-161	occ	250	lo	500	no-steam
115	4116-161	occ	250	lo	500	no-steam
116	4116-161	occ	250	lo	500	steam
117	4116-161	occ	250	lo	500	steam
118	4116-161	occ	250	lo	800	steam
119	4116-161	occ	250	lo	800	steam
120	4116-162	occ	250	hi	500	no-steam
121	4116-162	occ	250	hi	500	no-steam
122	4116-162	occ	250	hi	500	no-steam
123	4116-162	occ	250	hi	500	no-steam
124	4116-162	occ	250	hi	500	steam
125	4116-162	occ	250	hi	500	steam
126	4116-162	occ	250	hi	800	steam
127	4116-162	occ	250	hi	800	steam
128	4116-164	gl	500	low	500	no-steam
129	4116-164	gl	500	low	500	no-steam
130	4116-164	gl	500	low	500	no-steam
131	4116-164	gl	500	low	500	no-steam
132	4116-164	gl	500	low	500	steam
133	4116-164	gl	500	low	500	steam
134	4116-164	gl	500	low	800	steam
135	4116-164	gl	500	low	800	steam
136	4116-165	gl	500	hi	500	no-steam
137	4116-165	gl	500	hi	500	no-steam
138	4116-165	gl	500	hi	500	no-steam
139	4116-165	gl	500	hi	500	no-steam
140	4116-165	gl	500	hi	500	steam
141	4116-165	gl	500	hi	500	steam
142	4116-165	gl	500	hi	800	steam
143	4116-165	gl	500	hi	800	steam
144	4116-167	gl	350	low	500	no-steam

Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	LUB	MD Hygro. at 75.5% RH	MD Hygro. at 93.4% RH	CD Hygro. at 75.5% RH	CD Hygro. at 93.4% RH
109	no-wax	0.140	0.287	0.292	0.675
110	no-wax	0.140	0.287	0.292	0.675
111	no-wax	0.140	0.287	0.292	0.675
112	no-wax	0.111	0.231	0.369	0.87
113	no-wax	0.111	0.231	0.369	0.87
114	wax	0.111	0.231	0.369	0.87
115	wax	0.111	0.231	0.369	0.87
116	no-wax	0.111	0.231	0.369	0.87
117	no-wax	0.111	0.231	0.369	0.87
118	no-wax	0.111	0.231	0.369	0.87
119	no-wax	0.111	0.231	0.369	0.87
120	no-wax	.	.	.	.
121	no-wax	.	.	.	.
122	wax	.	.	.	.
123	wax	.	.	.	.
124	no-wax	.	.	.	.
125	no-wax	.	.	.	.
126	no-wax	.	.	.	.
127	no-wax	.	.	.	.
128	no-wax	0.152	0.326	0.334	0.771
129	no-wax	0.152	0.326	0.334	0.771
130	wax	0.152	0.326	0.334	0.771
131	wax	0.152	0.326	0.334	0.771
132	no-wax	0.152	0.326	0.334	0.771
133	no-wax	0.152	0.326	0.334	0.771
134	no-wax	0.152	0.326	0.334	0.771
135	no-wax	0.152	0.326	0.334	0.771
136	no-wax	0.155	0.329	0.313	0.690
137	no-wax	0.155	0.329	0.313	0.690
138	wax	0.155	0.329	0.313	0.690
139	wax	0.155	0.329	0.313	0.690
140	no-wax	0.155	0.329	0.313	0.690
141	no-wax	0.155	0.329	0.313	0.690
142	no-wax	0.155	0.329	0.313	0.690
143	no-wax	0.155	0.329	0.313	0.690
144	no-wax	0.160	0.335	0.453	1.060

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Basis Weight g/m2	Caliper	Density g/cm3	MD		CD		ZD	
				Elastic	Mod	Elastic	Mod	Elastic	Mod
				GPa		GPa		GPa	
109	130.35	250.55	0.5205	6.52		2.16		0.094	
110	130.35	250.55	0.5205	6.52		2.16		0.094	
111	130.35	250.55	0.5205	6.52		2.16		0.094	
112	131.90	237.40	0.5560	7.45		2.39		0.113	
113	131.90	237.40	0.5560	7.45		2.39		0.113	
114	131.90	237.40	0.5560	7.45		2.39		0.113	
115	131.90	237.40	0.5560	7.45		2.39		0.113	
116	131.90	237.40	0.5560	7.45		2.39		0.113	
117	131.90	237.40	0.5560	7.45		2.39		0.113	
118	131.90	237.40	0.5560	7.45		2.39		0.113	
119	131.90	237.40	0.5560	7.45		2.39		0.113	
120	133.30	233.60	0.5720	8.43		2.65		0.115	
121	133.30	233.60	0.5720	8.43		2.65		0.115	
122	133.30	233.60	0.5720	8.43		2.65		0.115	
123	133.30	233.60	0.5720	8.43		2.65		0.115	
124	133.30	233.60	0.5720	8.43		2.65		0.115	
125	133.30	233.60	0.5720	8.43		2.65		0.115	
126	133.30	233.60	0.5720	8.43		2.65		0.115	
127	133.30	233.60	0.5720	8.43		2.65		0.115	
128	130.80	392.30	0.3340	2.86		1.01		0.071	
129	130.80	392.30	0.3340	2.86		1.01		0.071	
130	130.80	392.30	0.3340	2.86		1.01		0.071	
131	130.80	392.30	0.3340	2.86		1.01		0.071	
132	130.80	392.30	0.3340	2.86		1.01		0.071	
133	130.80	392.30	0.3340	2.86		1.01		0.071	
134	130.80	392.30	0.3340	2.86		1.01		0.071	
135	130.80	392.30	0.3340	2.86		1.01		0.071	
136	131.70	396.90	0.3320	2.65		1.46		0.093	
137	131.70	396.90	0.3320	2.65		1.46		0.093	
138	131.70	396.90	0.3320	2.65		1.46		0.093	
139	131.70	396.90	0.3320	2.65		1.46		0.093	
140	131.70	396.90	0.3320	2.65		1.46		0.093	
141	131.70	396.90	0.3320	2.65		1.46		0.093	
142	131.70	396.90	0.3320	2.65		1.46		0.093	
143	131.70	396.90	0.3320	2.65		1.46		0.093	
144	136.50	377.00	0.3620	3.72		1.54		0.114	

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Shear Modulus GPa	Poisson Ratio CD/MD	MD Ring Crush lb/6 in	CD Ring Crush lb/6 in	MD STFI lb/6 in.	CD STFI lb/6 in.
109	1.35	0.405	53.11	35.80	24.18	11.23
110	1.35	0.405	53.11	35.80	24.18	11.23
111	1.35	0.405	53.11	35.80	24.18	11.23
112	1.50	0.427	52.78	37.39	28.54	17.46
113	1.50	0.427	52.78	37.39	28.54	17.46
114	1.50	0.427	52.78	37.39	28.54	17.46
115	1.50	0.427	52.78	37.39	28.54	17.46
116	1.50	0.427	52.78	37.39	28.54	17.46
117	1.50	0.427	52.78	37.39	28.54	17.46
118	1.50	0.427	52.78	37.39	28.54	17.46
119	1.50	0.427	52.78	37.39	28.54	17.46
120	1.66	0.456	51.57	42.71	30.67	13.43
121	1.66	0.456	51.57	42.71	30.67	13.43
122	1.66	0.456	51.57	42.71	30.67	13.43
123	1.66	0.456	51.57	42.71	30.67	13.43
124	1.66	0.456	51.57	42.71	30.67	13.43
125	1.66	0.456	51.57	42.71	30.67	13.43
126	1.66	0.456	51.57	42.71	30.67	13.43
127	1.66	0.456	51.57	42.71	30.67	13.43
128	0.61	0.420	47.59	34.00	20.77	9.29
129	0.61	0.420	47.59	34.00	20.77	9.29
130	0.61	0.420	47.59	34.00	20.77	9.29
131	0.61	0.420	47.59	34.00	20.77	9.29
132	0.61	0.420	47.59	34.00	20.77	9.29
133	0.61	0.420	47.59	34.00	20.77	9.29
134	0.61	0.420	47.59	34.00	20.77	9.29
135	0.61	0.420	47.59	34.00	20.77	9.29
136	0.65	0.470	45.04	32.04	21.43	10.17
137	0.65	0.470	45.04	32.04	21.43	10.17
138	0.65	0.470	45.04	32.04	21.43	10.17
139	0.65	0.470	45.04	32.04	21.43	10.17
140	0.65	0.470	45.04	32.04	21.43	10.17
141	0.65	0.470	45.04	32.04	21.43	10.17
142	0.65	0.470	45.04	32.04	21.43	10.17
143	0.65	0.470	45.04	32.04	21.43	10.17
144	0.86	0.443	69.89	48.00	28.27	14.94

Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Fluted Edge Crush lb/6 in.	Ratio of Fluted Edge Crush to CD RC	Model 1 Pred. Ratio of Edge Crush to CD RC	Ratio of Fluted Edge Crush to CD STFI
109	31.2	0.87	1.08	2.78
110	40.9	1.14	1.08	3.64
111	40.1	1.12	1.08	3.57
112	43.8	1.17	1.05	2.51
113	41.5	1.11	1.05	2.38
114	38.3	1.02	1.05	2.19
115	40.3	1.08	1.05	2.31
116	41.2	1.10	1.10	2.36
117	41.5	1.11	1.10	2.38
118	43.1	1.15	1.10	2.47
119	44.6	1.19	1.10	2.55
120	42.2	0.99	1.06	3.14
121	41.9	0.98	1.06	3.12
122	40.2	0.94	1.06	2.99
123	43.9	1.03	1.06	3.27
124	44.1	1.03	1.11	3.28
125	42.1	0.99	1.11	3.13
126	50.1	1.17	1.11	3.73
127	48.5	1.14	1.11	3.61
128	25.8	0.76	0.73	2.78
129	24.7	0.73	0.73	2.66
130	24.3	0.71	0.73	2.62
131	23.9	0.70	0.73	2.57
132	25.4	0.75	0.85	2.73
133	29.0	0.85	0.85	3.12
134	27.6	0.81	0.85	2.97
135	29.2	0.86	0.85	3.14
136	25.9	0.81	0.91	2.55
137	28.5	0.89	0.91	2.80
138	25.8	0.81	0.91	2.54
139	26.6	0.83	0.91	2.62
140	31.6	0.99	0.99	3.11
141	34.0	1.06	0.99	3.34
142	31.8	0.99	0.99	3.13
143	33.5	1.05	0.99	3.29
144	49.8	1.04	0.93	3.33

Project Database
Handsheets Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	MD Tensile	CD Tensile	MD TEA	CD TEA
109	10.630	3.097	158.50	68.08
110	10.630	3.097	158.50	68.08
111	10.630	3.097	158.50	68.08
112	11.720	3.360	166.10	78.13
113	11.720	3.360	166.10	78.13
114	11.720	3.360	166.10	78.13
115	11.720	3.360	166.10	78.13
116	11.720	3.360	166.10	78.13
117	11.720	3.360	166.10	78.13
118	11.720	3.360	166.10	78.13
119	11.720	3.360	166.10	78.13
120	12.900	3.715	194.00	73.25
121	12.900	3.715	194.00	73.25
122	12.900	3.715	194.00	73.25
123	12.900	3.715	194.00	73.25
124	12.900	3.715	194.00	73.25
125	12.900	3.715	194.00	73.25
126	12.900	3.715	194.00	73.25
127	12.900	3.715	194.00	73.25
128	4.681	1.891	29.07	21.77
129	4.681	1.891	29.07	21.77
130	4.681	1.891	29.07	21.77
131	4.681	1.891	29.07	21.77
132	4.681	1.891	29.07	21.77
133	4.681	1.891	29.07	21.77
134	4.681	1.891	29.07	21.77
135	4.681	1.891	29.07	21.77
136	5.630	2.294	41.80	28.08
137	5.630	2.294	41.80	28.08
138	5.630	2.294	41.80	28.08
139	5.630	2.294	41.80	28.08
140	5.630	2.294	41.80	28.08
141	5.630	2.294	41.80	28.08
142	5.630	2.294	41.80	28.08
143	5.630	2.294	41.80	28.08
144	7.791	3.375	72.33	53.15

**Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention**

----- Forming* Method=hand -----
(continued)

OBS	Sample ID	Pulp Source	Handsheet CS Freeness	Handsheet Pressure	Corrugator Speed fpm	Corrugator Presteaming
145	4116-167	gl	350	low	500	no-steam
146	4116-167	gl	350	low	500	no-steam
147	4116-167	gl	350	low	500	no-steam
148	4116-167	gl	350	low	500	steam
149	4116-167	gl	350	low	500	steam
150	4116-167	gl	350	low	800	steam
151	4116-167	gl	350	low	800	steam
152	4116-168	gl	350	hi	500	no-steam
153	4116-168	gl	350	hi	500	no-steam
154	4116-168	gl	350	hi	500	no-steam
155	4116-168	gl	350	hi	500	no-steam
156	4116-168	gl	350	hi	500	steam
157	4116-168	gl	350	hi	500	steam
158	4116-168	gl	350	hi	800	steam
159	4116-168	gl	350	hi	800	steam
160	4116-170	gl	250	low	500	no-steam
161	4116-170	gl	250	low	500	no-steam
162	4116-170	gl	250	low	500	no-steam
163	4116-170	gl	250	low	500	no-steam
164	4116-170	gl	250	low	500	steam
165	4116-170	gl	250	low	500	steam
166	4116-170	gl	250	low	800	steam
167	4116-170	gl	250	low	800	steam
168	4116-171	gl	250	hi	500	no-steam
169	4116-171	gl	250	hi	500	no-steam
170	4116-171	gl	250	hi	500	no-steam
171	4116-171	gl	250	hi	500	no-steam
172	4116-171	gl	250	hi	500	steam
173	4116-171	gl	250	hi	500	steam

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	LUB	MD Hygro. at 75.5% RH	MD Hygro. at 93.4% RH	CD Hygro. at 75.5% RH	CD Hygro. at 93.4% RH
145	no-wax	0.160	0.335	0.453	1.060
146	wax	0.160	0.335	0.453	1.060
147	wax	0.160	0.335	0.453	1.060
148	no-wax	0.160	0.335	0.453	1.060
149	no-wax	0.160	0.335	0.453	1.060
150	no-wax	0.160	0.335	0.453	1.060
151	no-wax	0.160	0.335	0.453	1.060
152	no-wax	0.171	0.380	0.331	0.722
153	no-wax	0.171	0.380	0.331	0.722
154	wax	0.171	0.380	0.331	0.722
155	wax	0.171	0.380	0.331	0.722
156	no-wax	0.171	0.380	0.331	0.722
157	no-wax	0.171	0.380	0.331	0.722
158	no-wax	0.171	0.380	0.331	0.722
159	no-wax	0.171	0.380	0.331	0.722
160	no-wax	.	.	.	.
161	no-wax	.	.	.	.
162	wax	.	.	.	.
163	wax	.	.	.	.
164	no-wax	.	.	.	.
165	no-wax	.	.	.	.
166	no-wax	.	.	.	.
167	no-wax	.	.	.	.
168	no-wax	0.183	0.405	0.374	0.836
169	no-wax	0.183	0.405	0.374	0.836
170	wax	0.183	0.405	0.374	0.836
171	wax	0.183	0.405	0.374	0.836
172	no-wax	0.183	0.405	0.374	0.836
173	no-wax	0.183	0.405	0.374	0.836

**Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention**

----- Forming* Method=hand -----
 (continued)

OBS	Basis Weight g/m ²	Caliper	Density g/cm ³	MD Elastic Mod GPa	CD Elastic Mod GPa	ZD Elastic Mod GPa
145	136.5	377.0	0.362	3.72	1.54	0.114
146	136.5	377.0	0.362	3.72	1.54	0.114
147	136.5	377.0	0.362	3.72	1.54	0.114
148	136.5	377.0	0.362	3.72	1.54	0.114
149	136.5	377.0	0.362	3.72	1.54	0.114
150	136.5	377.0	0.362	3.72	1.54	0.114
151	136.5	377.0	0.362	3.72	1.54	0.114
152	138.7	363.5	0.382	4.10	1.81	0.120
153	138.7	363.5	0.382	4.10	1.81	0.120
154	138.7	363.5	0.382	4.10	1.81	0.120
155	138.7	363.5	0.382	4.10	1.81	0.120
156	138.7	363.5	0.382	4.10	1.81	0.120
157	138.7	363.5	0.382	4.10	1.81	0.120
158	138.7	363.5	0.382	4.10	1.81	0.120
159	138.7	363.5	0.382	4.10	1.81	0.120
160	138.4	203.1	0.681	7.34	3.21	0.196
161	.	.	.	7.34	3.21	0.196
162	.	.	.	7.34	3.21	0.196
163	.	.	.	7.34	3.21	0.196
164	.	.	.	7.34	3.21	0.196
165	.	.	.	7.34	3.21	0.196
166	.	.	.	7.34	3.21	0.196
167	.	.	.	7.34	3.21	0.196
168	131.8	350.45	0.376	3.87	1.84	.
169	131.8	350.45	0.376	3.87	1.84	.
170	131.8	350.45	0.376	3.87	1.84	.
171	131.8	350.45	0.376	3.87	1.84	.
172	131.8	350.45	0.376	3.87	1.84	.
173	131.8	350.45	0.376	3.87	1.84	.

**Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention**

----- Forming* Method=hand -----
 (continued)

OBS	Shear Modulus GPa	Poisson Ratio CD/MD	MD Ring Crush lb/6 in	CD Ring Crush lb/6 in	MD STFI lb/6 in.	CD STFI lb/6 in.
145	0.860	0.443	69.89	48.00	28.27	14.94
146	0.860	0.443	69.89	48.00	28.27	14.94
147	0.860	0.443	69.89	48.00	28.27	14.94
148	0.860	0.443	69.89	48.00	28.27	14.94
149	0.860	0.443	69.89	48.00	28.27	14.94
150	0.860	0.443	69.89	48.00	28.27	14.94
151	0.860	0.443	69.89	48.00	28.27	14.94
152	1.000	0.440	73.45	52.08	30.39	16.40
153	1.000	0.440	73.45	52.08	30.39	16.40
154	1.000	0.440	73.45	52.08	30.39	16.40
155	1.000	0.440	73.45	52.08	30.39	16.40
156	1.000	0.440	73.45	52.08	30.39	16.40
157	1.000	0.440	73.45	52.08	30.39	16.40
158	1.000	0.440	73.45	52.08	30.39	16.40
159	1.000	0.440	73.45	52.08	30.39	16.40
160	1.780	0.420	71.78	52.46	30.98	16.82
161	1.780	0.420	71.78	52.46	30.98	16.82
162	1.780	0.420	71.78	52.46	30.98	16.82
163	1.780	0.420	71.78	52.46	30.98	16.82
164	1.780	0.420	71.78	52.46	30.98	16.82
165	1.780	0.420	71.78	52.46	30.98	16.82
166	1.780	0.420	71.78	52.46	30.98	16.82
167	1.780	0.420	71.78	52.46	30.98	16.82
168	0.985	0.405	71.84	51.84	30.13	18.18
169	0.985	0.405	71.84	51.84	30.13	18.18
170	0.985	0.405	71.84	51.84	30.13	18.18
171	0.985	0.405	71.84	51.84	30.13	18.18
172	0.985	0.405	71.84	51.84	30.13	18.18
173	0.985	0.405	71.84	51.84	30.13	18.18

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	Fluted Edge Crush lb/6 in.	Ratio of Fluted Edge Crush to CD RC	Model 1 Pred. Ratio of Edge Crush to CD RC	Ratio of Fluted Edge Crush to CD STFI
145	49.5	1.03	0.93	3.31
146	55.1	1.15	0.93	3.69
147	55.8	1.16	0.93	3.73
148	58.3	1.21	1.01	3.90
149	57.3	1.19	1.01	3.84
150	53.8	1.12	1.01	3.60
151	51.8	1.08	1.01	3.47
152	53.2	1.02	0.97	3.24
153	52.2	1.00	0.97	3.18
154	56.2	1.08	0.97	3.43
155	42.9	0.82	0.97	2.62
156	55.5	1.07	1.03	3.38
157	55.4	1.06	1.03	3.38
158	61.6	1.18	1.03	3.76
159	60.2	1.16	1.03	3.67
160	60.3	1.15	1.10	3.59
161	59.3	1.13	.	3.53
162	61.2	1.17	.	3.64
163	56.3	1.07	.	3.35
164	63.3	1.21	.	3.76
165	60.4	1.15	.	3.59
166	64.4	1.23	.	3.83
167	63.9	1.22	.	3.80
168	64.1	1.24	.	3.53
169	59.4	1.15	.	3.27
170	59.1	1.14	.	3.25
171	58.6	1.13	.	3.22
172	70.8	1.37	.	3.89
173	61.7	1.19	.	3.39

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=hand -----
 (continued)

OBS	MD Tensile	CD Tensile	MD TEA	CD TEA
145	7.791	3.375	72.33	53.15
146	7.791	3.375	72.33	53.15
147	7.791	3.375	72.33	53.15
148	7.791	3.375	72.33	53.15
149	7.791	3.375	72.33	53.15
150	7.791	3.375	72.33	53.15
151	7.791	3.375	72.33	53.15
152	8.732	3.782	91.38	63.56
153	8.732	3.782	91.38	63.56
154	8.732	3.782	91.38	63.56
155	8.732	3.782	91.38	63.56
156	8.732	3.782	91.38	63.56
157	8.732	3.782	91.38	63.56
158	8.732	3.782	91.38	63.56
159	8.732	3.782	91.38	63.56
160	.	.	.	.
161	.	.	.	.
162	.	.	.	.
163	.	.	.	.
164	.	.	.	.
165	.	.	.	.
166	.	.	.	.
167	.	.	.	.
168	9.156	3.722	104.82	41.43
169	9.156	3.722	104.82	41.43
170	9.156	3.722	104.82	41.43
171	9.156	3.722	104.82	41.43
172	9.156	3.722	104.82	41.43
173	9.156	3.722	104.82	41.43

Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----

OBS	Sample ID	Pulp Source	Handsheet CS Freeness	Handsheet Pressure	Corrugator Speed fpm	Corrugator Presteaming
174	4116-135	occ	.	.	500	no-steam
175	4116-135	occ	.	.	500	no-steam
176	4116-135	occ	.	.	800	no-steam
177	4116-135	occ	.	.	800	no-steam
178	4116-135	occ	.	.	800	no-steam
179	4116-135	occ	.	.	500	no-steam
180	4116-135	occ	.	.	500	no-steam
181	4116-135	occ	.	.	800	no-steam
182	4116-135	occ	.	.	800	no-steam
183	4116-135	occ	.	.	500	steam
184	4116-135	occ	.	.	500	steam
185	4116-135	occ	.	.	800	steam
186	4116-135	occ	.	.	800	steam
187	4116-140	nssc	.	.	500	no-steam
188	4116-140	nssc	.	.	500	no-steam
189	4116-140	nssc	.	.	800	no-steam
190	4116-140	nssc	.	.	800	no-steam
191	4116-140	nssc	.	.	500	no-steam
192	4116-140	nssc	.	.	500	no-steam
193	4116-140	nssc	.	.	800	no-steam
194	4116-140	nssc	.	.	800	no-steam
195	4116-140	nssc	.	.	500	steam
196	4116-140	nssc	.	.	500	steam
197	4116-140	nssc	.	.	800	steam
198	4116-140	nssc	.	.	800	steam
199	4116-141	gl	.	.	500	no-steam
200	4116-141	gl	.	.	500	no-steam
201	4116-141	gl	.	.	800	no-steam
202	4116-141	gl	.	.	800	no-steam
203	4116-141	gl	.	.	500	no-steam
204	4116-141	gl	.	.	500	no-steam
205	4116-141	gl	.	.	800	no-steam
206	4116-141	gl	.	.	800	no-steam
207	4116-141	gl	.	.	500	steam
208	4116-141	gl	.	.	500	steam
209	4116-141	gl	.	.	800	steam

Project Database
 Handsheet Conditions, Paper Properties
 Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----

OBS	LUB	MD Hygro. at 75.5% RH	MD Hygro. at 93.4% RH	CD Hygro. at 75.5% RH	CD Hygro. at 93.4% RH
174	no-wax	.	.	.	.
175	no-wax	.	.	.	.
176	no-wax	.	.	.	.
177	no-wax	.	.	.	.
178	no-wax	.	.	.	.
179	wax	.	.	.	.
180	wax	.	.	.	.
181	wax	.	.	.	.
182	wax	.	.	.	.
183	no-wax	.	.	.	.
184	no-wax	.	.	.	.
185	no-wax	.	.	.	.
186	no-wax	.	.	.	.
187	no-wax	.	.	.	.
188	no-wax	.	.	.	.
189	no-wax	.	.	.	.
190	no-wax	.	.	.	.
191	wax	.	.	.	.
192	wax	.	.	.	.
193	wax	.	.	.	.
194	wax	.	.	.	.
195	no-wax	.	.	.	.
196	no-wax	.	.	.	.
197	no-wax	.	.	.	.
198	no-wax	.	.	.	.
199	no-wax	.	.	.	.
200	no-wax	.	.	.	.
201	no-wax	.	.	.	.
202	no-wax	.	.	.	.
203	wax	.	.	.	.
204	wax	.	.	.	.
205	wax	.	.	.	.
206	wax	.	.	.	.
207	no-wax	.	.	.	.
208	no-wax	.	.	.	.
209	no-wax	.	.	.	.

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	Basis Weight g/m2	Caliper	Density g/cm3	MD Elastic Mod GPa	CD Elastic Mod GPa	ZD Elastic Mod GPa
174	128.10	196.6	0.6520	5.79	2.26	0.057
175	128.10	196.6	0.6520	5.79	2.26	0.057
176	128.10	196.6	0.6520	5.79	2.26	0.057
177	128.10	196.6	0.6520	5.79	2.26	0.057
178	128.10	196.6	0.6520	5.79	2.26	0.057
179	128.10	196.6	0.6520	5.79	2.26	0.057
180	128.10	196.6	0.6520	5.79	2.26	0.057
181	128.10	196.6	0.6520	5.79	2.26	0.057
182	128.10	196.6	0.6520	5.79	2.26	0.057
183	128.10	196.6	0.6520	5.79	2.26	0.057
184	128.10	196.6	0.6520	5.79	2.26	0.057
185	128.10	196.6	0.6520	5.79	2.26	0.057
186	128.10	196.6	0.6520	5.79	2.26	0.057
187	129.10	181.3	0.7120	6.49	3.17	0.152
188	129.10	181.3	0.7120	6.49	3.17	0.152
189	129.10	181.3	0.7120	6.49	3.17	0.152
190	129.10	181.3	0.7120	6.49	3.17	0.152
191	129.10	181.3	0.7120	6.49	3.17	0.152
192	129.10	181.3	0.7120	6.49	3.17	0.152
193	129.10	181.3	0.7120	6.49	3.17	0.152
194	129.10	181.3	0.7120	6.49	3.17	0.152
195	129.10	181.3	0.7120	6.49	3.17	0.152
196	129.10	181.3	0.7120	6.49	3.17	0.152
197	129.10	181.3	0.7120	6.49	3.17	0.152
198	129.10	181.3	0.7120	6.49	3.17	0.152
199	127.63	183.3	0.6963	6.40	2.87	0.151
200	127.63	183.3	0.6963	6.40	2.87	0.151
201	127.63	183.3	0.6963	6.40	2.87	0.151
202	127.63	183.3	0.6963	6.40	2.87	0.151
203	127.63	183.3	0.6963	6.40	2.87	0.151
204	127.63	183.3	0.6963	6.40	2.87	0.151
205	127.63	183.3	0.6963	6.40	2.87	0.151
206	127.63	183.3	0.6963	6.40	2.87	0.151
207	127.63	183.3	0.6963	6.40	2.87	0.151
208	127.63	183.3	0.6963	6.40	2.87	0.151
209	127.63	183.3	0.6963	6.40	2.87	0.151

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	Shear Modulus GPa	Poisson Ratio CD/MD	MD Ring Crush lb/6 in	CD Ring Crush lb/6 in	MD STFI lb/6 in.	CD STFI lb/6 in.
174	1.36	0.35	40.74	30.52	.	.
175	1.36	0.35	40.74	30.52	.	.
176	1.36	0.35	40.74	30.52	.	.
177	1.36	0.35	40.74	30.52	.	.
178	1.36	0.35	40.74	30.52	.	.
179	1.36	0.35	40.74	30.52	.	.
180	1.36	0.35	40.74	30.52	.	.
181	1.36	0.35	40.74	30.52	.	.
182	1.36	0.35	40.74	30.52	.	.
183	1.36	0.35	40.74	30.52	.	.
184	1.36	0.35	40.74	30.52	.	.
185	1.36	0.35	40.74	30.52	.	.
186	1.36	0.35	40.74	30.52	.	.
187	1.75	0.33	52.10	39.80	23.08	14.43
188	1.75	0.33	52.10	39.80	23.08	14.43
189	1.75	0.33	52.10	39.80	23.08	14.43
190	1.75	0.33	52.10	39.80	23.08	14.43
191	1.75	0.33	52.10	39.80	23.08	14.43
192	1.75	0.33	52.10	39.80	23.08	14.43
193	1.75	0.33	52.10	39.80	23.08	14.43
194	1.75	0.33	52.10	39.80	23.08	14.43
195	1.75	0.33	52.10	39.80	23.08	14.43
196	1.75	0.33	52.10	39.80	23.08	14.43
197	1.75	0.33	52.10	39.80	23.08	14.43
198	1.75	0.33	52.10	39.80	23.08	14.43
199	1.64	0.33	53.10	37.90	22.72	14.61
200	1.64	0.33	53.10	37.90	22.72	14.61
201	1.64	0.33	53.10	37.90	22.72	14.61
202	1.64	0.33	53.10	37.90	22.72	14.61
203	1.64	0.33	53.10	37.90	22.72	14.61
204	1.64	0.33	53.10	37.90	22.72	14.61
205	1.64	0.33	53.10	37.90	22.72	14.61
206	1.64	0.33	53.10	37.90	22.72	14.61
207	1.64	0.33	53.10	37.90	22.72	14.61
208	1.64	0.33	53.10	37.90	22.72	14.61
209	1.64	0.33	53.10	37.90	22.72	14.61

Project Database
Handsheets Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	Fluted Edge Crush lb/6 in.	Ratio of Fluted Edge Crush to CD RC	Model 1 Pred. Ratio of Edge Crush to CD STFI	Ratio of Fluted
174	28.86	0.95	0.96	.
175	30.64	1.00	0.96	.
176	29.83	0.98	0.96	.
177	30.36	0.99	0.96	.
178	29.83	0.98	0.96	.
179	30.50	1.00	0.96	.
180	32.28	1.06	0.96	.
181	29.94	0.98	0.96	.
182	30.75	1.01	0.96	.
183	33.30	1.09	1.01	.
184	33.55	1.10	1.01	.
185	31.53	1.03	1.01	.
186	31.22	1.02	1.01	.
187	46.16	1.16	1.11	3.20
188	45.25	1.14	1.11	3.14
189	42.24	1.06	1.11	2.93
190	43.81	1.10	1.11	3.04
191	47.16	1.18	1.11	3.27
192	46.88	1.18	1.11	3.25
193	44.84	1.13	1.11	3.11
194	46.49	1.17	1.11	3.22
195	45.91	1.15	1.15	3.18
196	47.11	1.18	1.15	3.26
197	47.04	1.18	1.15	3.26
198	46.42	1.17	1.15	3.22
199	44.61	1.18	1.09	3.05
200	41.36	1.09	1.09	2.83
201	42.33	1.12	1.09	2.90
202	40.50	1.07	1.09	2.77
203	48.49	1.28	1.09	3.32
204	46.85	1.24	1.09	3.21
205	46.07	1.22	1.09	3.15
206	44.35	1.17	1.09	3.04
207	50.51	1.33	1.13	3.46
208	47.58	1.26	1.13	3.26
209	44.89	1.18	1.13	3.07

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	MD Tensile	CD Tensile	MD TEA	CD TEA
174	.	.	.	.
175	.	.	.	.
176	.	.	.	.
177	.	.	.	.
178	.	.	.	.
179	.	.	.	.
180	.	.	.	.
181	.	.	.	.
182	.	.	.	.
183	.	.	.	.
184	.	.	.	.
185	.	.	.	.
186	.	.	.	.
187	7.170	3.25	69.76	74.75
188	7.170	3.25	69.76	74.75
189	7.170	3.25	69.76	74.75
190	7.170	3.25	69.76	74.75
191	7.170	3.25	69.76	74.75
192	7.170	3.25	69.76	74.75
193	7.170	3.25	69.76	74.75
194	7.170	3.25	69.76	74.75
195	7.170	3.25	69.76	74.75
196	7.170	3.25	69.76	74.75
197	7.170	3.25	69.76	74.75
198	7.170	3.25	69.76	74.75
199	6.930	2.86	70.72	56.98
200	6.930	2.86	70.72	56.98
201	6.930	2.86	70.72	56.98
202	6.930	2.86	70.72	56.98
203	6.930	2.86	70.72	56.98
204	6.930	2.86	70.72	56.98
205	6.930	2.86	70.72	56.98
206	6.930	2.86	70.72	56.98
207	6.930	2.86	70.72	56.98
208	6.930	2.86	70.72	56.98
209	6.930	2.86	70.72	56.98

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	Sample ID	Pulp Source	Handsheet CS Freeness	Handsheet Pressure	Corrugator Speed fpm	Corrugator Presteaming
210	4116-141	gl	.	.	800	steam
211	4116-142	cc	.	.	500	no-steam
212	4116-142	cc	.	.	500	no-steam
213	4116-142	cc	.	.	800	no-steam
214	4116-142	cc	.	.	800	no-steam
215	4116-142	cc	.	.	500	no-steam
216	4116-142	cc	.	.	500	no-steam
217	4116-142	cc	.	.	800	no-steam
218	4116-142	cc	.	.	800	no-steam
219	4116-142	cc	.	.	500	steam
220	4116-142	cc	.	.	500	steam
221	4116-142	cc	.	.	800	steam
222	4116-142	cc	.	.	800	steam

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	LUB	MD Hygro. at 75.5% RH	MD Hygro. at 93.4% RH	CD Hygro. at 75.5% RH	CD Hygro. at 93.4% RH
210	no-wax	.	.	.	.
211	no-wax	.	.	.	.
212	no-wax	.	.	.	.
213	no-wax	.	.	.	.
214	no-wax	.	.	.	.
215	wax	.	.	.	.
216	wax	.	.	.	.
217	wax	.	.	.	.
218	wax	.	.	.	.
219	no-wax	.	.	.	.
220	no-wax	.	.	.	.
221	no-wax	.	.	.	.
222	no-wax	.	.	.	.

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	Basis Weight g/m ²	Caliper	Density g/cm ³	MD Elastic Mod GPa	CD Elastic Mod GPa	ZD Elastic Mod GPa
210	127.63	183.3	0.6963	6.40	2.87	0.151
211	125.45	198.5	0.6320	5.68	2.48	0.116
212	125.45	198.5	0.6320	5.68	2.48	0.116
213	125.45	198.5	0.6320	5.68	2.48	0.116
214	125.45	198.5	0.6320	5.68	2.48	0.116
215	125.45	198.5	0.6320	5.68	2.48	0.116
216	125.45	198.5	0.6320	5.68	2.48	0.116
217	125.45	198.5	0.6320	5.68	2.48	0.116
218	125.45	198.5	0.6320	5.68	2.48	0.116
219	125.45	198.5	0.6320	5.68	2.48	0.116
220	125.45	198.5	0.6320	5.68	2.48	0.116
221	125.45	198.5	0.6320	5.68	2.48	0.116
222	125.45	198.5	0.6320	5.68	2.48	0.116

Project Database
Handsheets Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	Shear Modulus GPa	Poisson Ratio CD/MD	MD		CD	
			Ring Crush lb/6 in	Ring Crush lb/6 in	MD STFI lb/6 in.	CD STFI lb/6 in.
210	1.64	0.33	53.1	37.9	22.72	14.61
211	1.44	0.33	52.1	39.8	20.99	12.86
212	1.44	0.33	52.1	39.8	20.99	12.86
213	1.44	0.33	52.1	39.8	20.99	12.86
214	1.44	0.33	52.1	39.8	20.99	12.86
215	1.44	0.33	52.1	39.8	20.99	12.86
216	1.44	0.33	52.1	39.8	20.99	12.86
217	1.44	0.33	52.1	39.8	20.99	12.86
218	1.44	0.33	52.1	39.8	20.99	12.86
219	1.44	0.33	52.1	39.8	20.99	12.86
220	1.44	0.33	52.1	39.8	20.99	12.86
221	1.44	0.33	52.1	39.8	20.99	12.86
222	1.44	0.33	52.1	39.8	20.99	12.86

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
 (continued)

OBS	Fluted Edge Crush lb/6 in.	Ratio of Fluted Edge Crush to CD RC	Model 1 Pred. Ratio of Edge Crush to CD STFI	Ratio of Fluted Edge Crush
210	43.54	1.15	1.13	2.98
211	42.13	1.06	1.05	3.28
212	40.31	1.01	1.05	3.13
213	37.91	0.95	1.05	2.95
214	37.75	0.95	1.05	2.94
215	42.05	1.06	1.05	3.27
216	42.05	1.06	1.05	3.27
217	36.63	0.92	1.05	2.85
218	38.11	0.96	1.05	2.96
219	40.20	1.01	1.09	3.13
220	39.86	1.00	1.09	3.10
221	38.83	0.98	1.09	3.02
222	40.24	1.01	1.09	3.13

Project Database
Handsheet Conditions, Paper Properties
Corrugating Conditions and Strength Retention

----- Forming* Method=machine -----
(continued)

OBS	MD Tensile	CD Tensile	MD TEA	CD TEA
210	6.930	2.86	70.72	56.98
211	6.522	2.82	62.44	50.46
212	6.522	2.82	62.44	50.46
213	6.522	2.82	62.44	50.46
214	6.522	2.82	62.44	50.46
215	6.522	2.82	62.44	50.46
216	6.522	2.82	62.44	50.46
217	6.522	2.82	62.44	50.46
218	6.522	2.82	62.44	50.46
219	6.522	2.82	62.44	50.46
220	6.522	2.82	62.44	50.46
221	6.522	2.82	62.44	50.46
222	6.522	2.82	62.44	50.46

APPENDIX D

CORRELATION ANALYSIS
 Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0
 / Number of Observations

	IEX	IEY	IEZ	IR1	IG
IEX	1.00000 0.0 222	0.71347 0.0001 222	0.21264 0.0017 216	0.16450 0.0160 214	0.88396 0.0001 222
IEY	0.71347 0.0001 222	1.00000 0.0 222	0.48189 0.0001 216	0.74219 0.0001 214	0.95032 0.0001 222
IEZ	0.21264 0.0017 216	0.48189 0.0001 216	1.00000 0.0 216	0.68273 0.0001 208	0.39720 0.0001 216
IR1	0.16450 0.0160 214	0.74219 0.0001 214	0.68273 0.0001 208	1.00000 0.0 214	0.54686 0.0001 214
IG	0.88396 0.0001 222	0.95032 0.0001 222	0.39720 0.0001 216	0.54686 0.0001 214	1.00000 0.0 222
G21	0.23470 0.0004 222	0.61214 0.0001 222	0.18952 0.0052 216	0.43018 0.0001 214	0.55140 0.0001 222
HYGMDH	0.35921 0.0001 110	0.21885 0.0216 110	0.04150 0.6758 104	-0.05928 0.5385 110	0.27336 0.0039 110
HYGMDM	0.32483 0.0005 110	0.29423 0.0018 110	-0.09766 0.3240 104	0.05373 0.5772 110	0.30062 0.0014 110
HYGCDM	0.05094 0.5972 110	0.29905 0.0015 110	-0.37137 0.0001 104	0.14385 0.1338 110	0.20822 0.0290 110
HYGCDH	0.03328 0.7300 110	0.28861 0.0022 110	-0.30750 0.0015 104	0.15280 0.1110 110	0.19041 0.0463 110

CORRELATION ANALYSIS

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0
/ Number of Observations

	G21	HYGMDH	HYGMDM	HYGCDM	HYGCDH
IEX	0.23470 0.0004 222	0.35921 0.0001 110	0.32483 0.0005 110	0.05094 0.5972 110	0.03328 0.7300 110
IEY	0.61214 0.0001 222	0.21885 0.0216 110	0.29423 0.0018 110	0.29905 0.0015 110	0.28861 0.0022 110
IEZ	0.18952 0.0052 216	0.04150 0.6758 104	-0.09766 0.3240 104	-0.37137 0.0001 104	-0.30750 0.0015 104
IR1	0.43018 0.0001 214	-0.05928 0.5385 110	0.05373 0.5772 110	0.14385 0.1338 110	0.15280 0.1110 110
IG	0.55140 0.0001 222	0.27336 0.0039 110	0.30062 0.0014 110	0.20822 0.0290 110	0.19041 0.0463 110
G21	1.00000 0.0 222	-0.04885 0.6123 110	0.07662 0.4263 110	0.47796 0.0001 110	0.45253 0.0001 110
HYGMDH	-0.04885 0.6123 110	1.00000 0.0 110	0.93681 0.0001 110	0.18055 0.0591 110	0.08513 0.3766 110
HYGMDM	0.07662 0.4263 110	0.93681 0.0001 110	1.00000 0.0 110	0.29065 0.0021 110	0.17167 0.0729 110
HYGCDM	0.47796 0.0001 110	0.18055 0.0591 110	0.29065 0.0021 110	1.00000 0.0 110	0.98267 0.0001 110
HYGCDH	0.45253 0.0001 110	0.08513 0.3766 110	0.17167 0.0729 110	0.98267 0.0001 110	1.00000 0.0 110

CORRELATION ANALYSIS

10 'VAR' Variables: IEX IEY IEZ IR1 IG G21
 HYGMDH HYGMDM HYGCDM HYGCDH

CORRELATION ANALYSIS

Simple Statistics

Variable	N	Mean	Std Dev	Sum
IEX	222	0.22160	0.07340	49.19463
IEY	222	0.55012	0.20156	122.12736
IEZ	216	9.78239	3.77616	2113
IR1	214	0.25359	0.05035	54.26925
IG	222	0.95517	0.33066	212.04730
G21	222	0.40106	0.05062	89.03600
HYGMDH	110	0.34020	0.04549	37.42200
HYGMDM	110	0.16293	0.02153	17.92200
HYGCDM	110	0.33742	0.07339	37.11600
HYGCDH	110	0.75658	0.15681	83.22400

CORRELATION ANALYSIS

Simple Statistics

Variable	Minimum	Maximum
IEX	0.11862	0.37736
IEY	0.31153	1.04167
IEZ	5.10204	19.23077
IR1	0.18706	0.41583
IG	0.56180	1.63934
G21	0.33000	0.50000
HYGMDH	0.23100	0.40500
HYGMDM	0.11100	0.19600
HYGCDM	0.23500	0.51100
HYGCDH	0.53900	1.06600

APPENDIX E

**Measured vs. Predicted Converting Ratio
Model 1
General Linear Models Procedure
Class Level Information**

Number of observations in data set = 222

NOTE: Due to missing values, only 204 observations can be used in this analysis.

Dependent Variable: T1

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	2.45896978	0.35128140	49.00	0.0001
Error	196	1.40517927	0.00716928		
Corrected Total	203	3.86414905			

R-Square	C.V.	Root MSE	T1 Mean
0.636355	8.537349	0.084672	0.99177874

Source	DF	Type I SS	Mean Square	F Value	Pr > F
IEX	1	1.00860193	1.00860193	140.68	0.0001
IEY	1	1.00915282	1.00915282	140.76	0.0001
IEZ	1	0.13745262	0.13745262	19.17	0.0001
IR1	1	0.01119713	0.01119713	1.56	0.2129
IG	1	0.00780001	0.00780001	1.09	0.2982
G21	1	0.02481707	0.02481707	3.46	0.0643
IEY*STEAM	1	0.25994819	0.25994819	36.26	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
IEX	1	0.04773471	0.04773471	6.66	0.0106
IEY	1	0.05747174	0.05747174	8.02	0.0051
IEZ	1	0.02823958	0.02823958	3.94	0.0486
IR1	1	0.02948249	0.02948249	4.11	0.0439
IG	1	0.03643403	0.03643403	5.08	0.0253
G21	1	0.03268565	0.03268565	4.56	0.0340
IEY*STEAM	1	0.25994819	0.25994819	36.26	0.0001

Dependent Variable: T1

Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	1.739562630	9.56	0.0001	0.18194914
IEX	-1.901264467	-2.58	0.0106	0.73682305
IEY	-0.607086130 B	-2.58	0.0107	0.23565781
IEZ	-0.004842329	-1.98	0.0486	0.00243985
IR1	-0.931700086	-2.03	0.0439	0.45944323
IG	0.634489806	2.25	0.0253	0.28145496
G21	-0.689409564	-2.14	0.0340	0.32287659
IEY*STEAM no	-0.120476108 B	-6.02	0.0001	0.02000762
yes	0.000000000 B	.	.	.

**Measured vs. Predicted Converting Ratio
Model 1
General Linear Models Procedure**

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

Observation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
1	0.88333333	0.94893749 -0.06560416	0.77837559 1.11949939
2	0.83373984	0.94893749 -0.11519765	0.77837559 1.11949939
3	0.97154472	0.94893749 0.02260722	0.77837559 1.11949939
4	0.91463415	0.94893749 -0.03430334	0.77837559 1.11949939
5	1.01422764	1.01513315 -0.00090551	0.84450509 1.18576122
6	0.98983740	1.01513315 -0.02529576	0.84450509 1.18576122
7	0.95528455	1.01513315 -0.05984860	0.84450509 1.18576122
8	0.94918699	1.01513315 -0.06594616	0.84450509 1.18576122
9 *	.	0.93120171 .	0.76034551 1.10205791
10	0.89536290	0.93120171 -0.03583881	0.76034551 1.10205791
11	0.93145161	0.93120171 0.00024990	0.76034551 1.10205791
12	0.92338710	0.93120171 -0.00781461	0.76034551 1.10205791
13 *	.	1.00084108 .	0.82991466 1.17176750
14	0.97782258	1.00084108 -0.02301850	0.82991466 1.17176750
15 *	.	1.00084108 .	0.82991466 1.17176750
16	0.99596774	1.00084108 -0.00487334	0.82991466 1.17176750
17	0.88217636	0.95880774 -0.07663138	0.78979293 1.12782256
18	0.92007505	0.95880774 -0.03873270	0.78979293 1.12782256
19	0.90619137	0.95880774 -0.05261637	0.78979293 1.12782256
20	0.94596623	0.95880774 -0.01284152	0.78979293 1.12782256
21	0.93621013	1.02289078 -0.08668065	0.85382984 1.19195172

Observation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
22	1.05440901	1.02289078	0.85382984
		0.03151823	1.19195172
23	0.92495310	1.02289078	0.85382984
		-0.09793768	1.19195172
24	1.17823640	1.02289078	0.85382984
		0.15534562	1.19195172
25	1.05037175	1.01782463	0.84838265
		0.03254712	1.18726661
26	1.03847584	1.01782463	0.84838265
		0.02065121	1.18726661
27	1.01115242	1.01782463	0.84838265
		-0.00667221	1.18726661
28	0.99070632	1.01782463	0.84838265
		-0.02711831	1.18726661
29	1.16356877	1.07308890	0.90355664
		0.09047987	1.24262116
30	1.15241636	1.07308890	0.90355664
		0.07932746	1.24262116
31	0.97955390	1.07308890	0.90355664
		-0.09353500	1.24262116
32	1.20631970	1.07308890	0.90355664
		0.13323080	1.24262116
33	0.70887372	0.62584664	0.45136626
		0.08302709	0.80032701
34	0.70000000	0.62584664	0.45136626
		0.07415336	0.80032701
35	0.59726962	0.62584664	0.45136626
		-0.02857701	0.80032701
36	0.55631399	0.62584664	0.45136626
		-0.06953264	0.80032701
37	0.76109215	0.75134258	0.57688179
		0.00974957	0.92580337
38	0.68600683	0.75134258	0.57688179
		-0.06533575	0.92580337
39	0.78156997	0.75134258	0.57688179
		0.03022738	0.92580337
40	0.78156997	0.75134258	0.57688179
		0.03022738	0.92580337
41	0.82842466	0.74547155	0.57304761
		0.08295311	0.91789549
42	0.80924658	0.74547155	0.57304761
		0.06377502	0.91789549
43	0.89726027	0.86778232	0.69534234
		0.02947795	1.04022230
44	0.81849315	0.86778232	0.69534234
		-0.04928917	1.04022230
45	0.70890411	0.74547155	0.57304761
		-0.03656744	0.91789549
46	0.61986301	0.74547155	0.57304761
		-0.12560854	0.91789549

Observation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
47	0.88356164	0.86778232 0.01577932	0.69534234 1.04022230
48	0.77397260	0.86778232 -0.09380972	0.69534234 1.04022230
49	1.02189781	0.97354690 0.04835091	0.80467867 1.14241512
50	0.98060480	0.97354690 0.00705790	0.80467867 1.14241512
51	0.96558916	0.97354690 -0.00795774	0.80467867 1.14241512
52	1.00104275	0.97354690 0.02749586	0.80467867 1.14241512
53	1.06360792	1.04700794 0.01659999	0.87818903 1.21582684
54	0.99061522	1.04700794 -0.05639271	0.87818903 1.21582684
55	1.03858186	1.04700794 -0.00842608	0.87818903 1.21582684
56	1.01147028	1.04700794 -0.03553766	0.87818903 1.21582684
57	0.99140351	0.94973681 0.04166670	0.78074659 1.11872702
58	0.98017544	0.94973681 0.03043863	0.78074659 1.11872702
59	0.84561404	0.94973681 -0.10412277	0.78074659 1.11872702
60	0.85614035	0.94973681 -0.09359645	0.78074659 1.11872702
61	0.94210526	1.02746333 -0.08535806	0.85840527 1.19652138
62	0.96315789	1.02746333 -0.06430543	0.85840527 1.19652138
63	0.94561404	1.02746333 -0.08184929	0.85840527 1.19652138
64	0.95789474	1.02746333 -0.06956859	0.85840527 1.19652138
65	0.90996119	0.82547286 0.08448833	0.65508840 0.99585732
66	0.89262613	0.82547286 0.06715327	0.65508840 0.99585732
67	0.82535576	0.82547286 -0.00011710	0.65508840 0.99585732
68	0.81759379	0.82547286 -0.00787907	0.65508840 0.99585732
69	0.98835705	0.92503989 0.06331716	0.75492209 1.09515769
70	0.91849935	0.92503989 -0.00654054	0.75492209 1.09515769
71	0.95472186	0.92503989 0.02968197	0.75492209 1.09515769

Observation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
72	0.97542044	0.92503989 0.05038055	0.75492209 1.09515769
73 *	.	1.03546248	0.86166708 1.20925787
74 *			
75	0.86590909	1.03546248 -0.16955338	0.86166708 1.20925787
76	1.06818182	1.08270801 -0.01452619	0.90896785 1.25644817
77	1.02045455	1.08270801 -0.06225346	0.90896785 1.25644817
78	1.05000000	1.08270801 -0.03270801	0.90896785 1.25644817
79	1.07272727	1.08270801 -0.00998074	0.90896785 1.25644817
80	0.81285021	0.91047680 -0.09762659	0.74010085 1.08085274
81	0.83078072	0.91047680 -0.07969607	0.74010085 1.08085274
82	0.91893911	0.91047680 0.00846231	0.74010085 1.08085274
83	0.91520359	0.91047680 0.00472679	0.74010085 1.08085274
84	0.91146806	0.97892913 -0.06746107	0.80836470 1.14949356
85	0.95255883	0.97892913 -0.02637030	0.80836470 1.14949356
86	1.10571535	0.97892913 0.12678622	0.80836470 1.14949356
87	1.03474038	0.97892913 0.05581125	0.80836470 1.14949356
88	0.88215712	1.01702596 -0.13486884	0.84896402 1.18508791
89	0.87549933	1.01702596 -0.14152663	0.84896402 1.18508791
90	0.85219707	1.01702596 -0.16482889	0.84896402 1.18508791
91	0.89880160	1.01702596 -0.11822436	0.84896402 1.18508791
92	0.86218375	1.07254491 -0.21036115	0.90442125 1.24066856
93	0.80559254	1.07254491 -0.26695236	0.90442125 1.24066856
94	0.98535286	1.07254491 -0.08719204	0.90442125 1.24066856
95	0.92210386	1.07254491 -0.15044104	0.90442125 1.24066856
96	0.93224932	1.03014879 -0.09789946	0.86150537 1.19879220

bservation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
97	0.97669377	1.03014879	0.86150537
		-0.05345502	1.19879220
98	0.94850949	1.03014879	0.86150537
		-0.08163930	1.19879220
99	1.07967480	1.03014879	0.86150537
		0.04952601	1.19879220
100	1.12466125	1.09298169	0.92449784
		0.03167955	1.26146554
101	1.10298103	1.08592476	0.91721202
		0.01705627	1.25463750
102	1.01626016	1.08592476	0.91721202
		-0.06966460	1.25463750
103	1.04065041	1.09298169	0.92449784
		-0.05233129	1.26146554
104	1.12569832	1.02587688	0.85696191
		0.09982144	1.19479185
105	1.20670391	1.02587688	0.85696191
		0.18082703	1.19479185
106	1.03351955	1.02587688	0.85696191
		0.00764267	1.19479185
107	0.98603352	1.02587688	0.85696191
		-0.03984336	1.19479185
108	1.08379888	1.08165286	0.91266027
		0.00214602	1.25064545
109	0.87150838	1.08165286	0.91266027
		-0.21014448	1.25064545
110	1.14245810	1.08165286	0.91266027
		0.06080524	1.25064545
111	1.12011173	1.08165286	0.91266027
		0.03845887	1.25064545
112	1.17143621	1.04895589	0.88020278
		0.12248032	1.21770899
113	1.10992244	1.04895589	0.88020278
		0.06096655	1.21770899
114	1.02433806	1.04895589	0.88020278
		-0.02461783	1.21770899
115	1.07782830	1.04895589	0.88020278
		0.02887241	1.21770899
116	1.10189890	1.09936430	0.93060979
		0.00253460	1.26811881
117	1.10992244	1.09936430	0.93060979
		0.01055814	1.26811881
118	1.15271463	1.09936430	0.93060979
		0.05335033	1.26811881
119	1.19283231	1.09936430	0.93060979
		0.09346801	1.26811881
120	0.98805900	1.06411354	0.89383616
		-0.07605454	1.23439092
121	0.98103489	1.06411354	0.89383616
		-0.08307866	1.23439092

Observation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
122	0.94123156	1.06411354 -0.12288198	0.89383616 1.23439092
123	1.02786233	1.06411354 -0.03625121	0.89383616 1.23439092
124	1.03254507	1.10957622 -0.07703115	0.93936634 1.27978611
125	0.98571763	1.10957622 -0.12385859	0.93936634 1.27978611
126	1.17302739	1.10957622 0.06345117	0.93936634 1.27978611
127	1.13556544	1.10957622 0.02598922	0.93936634 1.27978611
128	0.75882353	0.72871283 0.03011070	0.55727934 0.90014631
129	0.72647059	0.72871283 -0.00224224	0.55727934 0.90014631
130	0.71470588	0.72871283 -0.01400694	0.55727934 0.90014631
131	0.70294118	0.72871283 -0.02577165	0.55727934 0.90014631
132	0.74705882	0.84799610 -0.10093728	0.67640557 1.01958663
133	0.85294118	0.84799610 0.00494508	0.67640557 1.01958663
134	0.81176471	0.84799610 -0.03623140	0.67640557 1.01958663
135	0.85882353	0.84799610 0.01082743	0.67640557 1.01958663
136	0.80836454	0.91195561 -0.10359107	0.73453013 1.08938110
137	0.88951311	0.91195561 -0.02244250	0.73453013 1.08938110
138	0.80524345	0.91195561 -0.10671217	0.73453013 1.08938110
139	0.83021223	0.91195561 -0.08174338	0.73453013 1.08938110
140	0.98626717	0.99447349 -0.00820633	0.81702857 1.17191842
141	1.06117353	0.99447349 0.06670004	0.81702857 1.17191842
142	0.99250936	0.99447349 -0.00196413	0.81702857 1.17191842
143	1.04556804	0.99447349 0.05109455	0.81702857 1.17191842
144	1.03750000	0.92691084 0.11058916	0.75821941 1.09560227
145	1.03125000	0.92691084 0.10433916	0.75821941 1.09560227
146	1.14791667	0.92691084 0.22100583	0.75821941 1.09560227

Observation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
147	1.16250000	0.92691084 0.23558916	0.75821941 1.09560227
148	1.21458333	1.00514208 0.20944125	0.83653669 1.17374747
149	1.19375000	1.00514208 0.18860792	0.83653669 1.17374747
150	1.12083333	1.00514208 0.11569125	0.83653669 1.17374747
151	1.07916667	1.00514208 0.07402459	0.83653669 1.17374747
152	1.02150538	0.96803332 0.05347206	0.79870822 1.13735841
153	1.00230415	0.96803332 0.03427083	0.79870822 1.13735841
154	1.07910906	0.96803332 0.11107575	0.79870822 1.13735841
155	0.82373272	0.96803332 -0.14430060	0.79870822 1.13735841
156	1.06566820	1.03459470 0.03107350	0.86538074 1.20380867
157	1.06374808	1.03459470 0.02915338	0.86538074 1.20380867
158	1.18279570	1.03459470 0.14820100	0.86538074 1.20380867
159	1.15591398	1.03459470 0.12131928	0.86538074 1.20380867
160	1.14944720	1.09841730 0.05102989	0.92794722 1.26888739
161	*		
162	*		
163	*		
164	*		
165	*		
166	*		
167	*		
168	*		
169	*		
170	*		
171	*		
172	*		
173	*		
174	0.94560944	0.96076085 -0.01515141	0.79035008 1.13117162
175	1.00393185	0.96076085 0.04317100	0.79035008 1.13117162
176	0.97739187	0.96076085 0.01663102	0.79035008 1.13117162
177	0.99475754	0.96076085 0.03399669	0.79035008 1.13117162
178	0.97739187	0.96076085 0.01663102	0.79035008 1.13117162

Observation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
179	0.99934469	0.96076085 0.03858384	0.79035008 1.13117162
180	1.05766710	0.96076085 0.09690625	0.79035008 1.13117162
181	0.98099607	0.96076085 0.02023522	0.79035008 1.13117162
182	1.00753604	0.96076085 0.04677519	0.79035008 1.13117162
183	1.09108781	1.01406886 0.07701895	0.84340160 1.18473612
184	1.09927916	1.01406886 0.08521030	0.84340160 1.18473612
185	1.03309305	1.01406886 0.01902419	0.84340160 1.18473612
186	1.02293578	1.01406886 0.00886692	0.84340160 1.18473612
187	1.15979899	1.11103270 0.04876630	0.94220912 1.27985627
188	1.13693467	1.11103270 0.02590198	0.94220912 1.27985627
189	1.06130653	1.11103270 -0.04972617	0.94220912 1.27985627
190	1.10075377	1.11103270 -0.01027893	0.94220912 1.27985627
191	1.18492462	1.11103270 0.07389192	0.94220912 1.27985627
192	1.17788945	1.11103270 0.06685675	0.94220912 1.27985627
193	1.12663317	1.11103270 0.01560047	0.94220912 1.27985627
194	1.16809045	1.11103270 0.05705775	0.94220912 1.27985627
195	1.15351759	1.14903778 0.00447981	0.98007482 1.31800074
196	1.18366834	1.14903778 0.03463056	0.98007482 1.31800074
197	1.18190955	1.14903778 0.03287177	0.98007482 1.31800074
198	1.16633166	1.14903778 0.01729388	0.98007482 1.31800074
199	1.17704485	1.09025174 0.08679311	0.92095360 1.25954989
200	1.09129288	1.09025174 0.00104113	0.92095360 1.25954989
201	1.11688654	1.09025174 0.02663480	0.92095360 1.25954989
202	1.06860158	1.09025174 -0.02165016	0.92095360 1.25954989
203	1.27941953	1.09025174 0.18916778	0.92095360 1.25954989

Observation	Observed	Predicted Residual	Lower 95% CLI Upper 95% CLI
204	1.23614776	1.09025174 0.14589601	0.92095360 1.25954989
205	1.21556728	1.09025174 0.12531554	0.92095360 1.25954989
206	1.17018470	1.09025174 0.07993295	0.92095360 1.25954989
207	1.33271768	1.13222948 0.20048820	0.96277038 1.30168859
208	1.25540897	1.13222948 0.12317949	0.96277038 1.30168859
209	1.18443272	1.13222948 0.05220324	0.96277038 1.30168859
210	1.14881266	1.13222948 0.01658318	0.96277038 1.30168859
211	1.05854271	1.04539640 0.01314631	0.87660291 1.21418990
212	1.01281407	1.04539640 -0.03258233	0.87660291 1.21418990
213	0.95251256	1.04539640 -0.09288384	0.87660291 1.21418990
214	0.94849246	1.04539640 -0.09690394	0.87660291 1.21418990
215	1.05653266	1.04539640 0.01113626	0.87660291 1.21418990
216	1.05653266	1.04539640 0.01113626	0.87660291 1.21418990
217	0.92035176	1.04539640 -0.12504465	0.87660291 1.21418990
218	0.95753769	1.04539640 -0.08785872	0.87660291 1.21418990
219	1.01005025	1.09397548 -0.08392523	0.92498693 1.26296403
220	1.00150754	1.09397548 -0.09246794	0.92498693 1.26296403
221	0.97562814	1.09397548 -0.11834734	0.92498693 1.26296403
222	1.01105528	1.09397548 -0.08292020	0.92498693 1.26296403

* Observation was not used in this analysis

Sum of Residuals	0.00000000
Sum of Squared Residuals	1.40517927
Sum of Squared Residuals - Error SS	-0.00000000
Press Statistic	1.50044918
First Order Autocorrelation	0.51121108
Durbin-Watson D	0.96962180

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