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The Effects of Furnish and Supercalendering on Rotogravure Printability of Uncoated Papers

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THE EFFECTS OF FURNISH AND SUPERCALENDERING ON ROTOGRAVURE PRINTABILITY OF UNCOATED PAPERS

BY

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ABSTRACT

A comparison was made of the surface and printing properties of eucalyptus and loblolly handsheets which were subjected to different supercalendering conditions. Supercalendering nip pressure was kept constant (2000 pli). The different supercalendering conditions investigated were the effects of the steel and filled rolls on the paper quality produced. The differences between the two pulps were large and this was attributed to the compressible nature of the two different fiber network structures. The more compressible eucalyptus sheet obtained better surface and printing properties at a given nip pressure. The eucalyptus sheet also showed no significant change in properties obtained under different supercalendering conditions. The less compressible loblolly sheet showed less response to nip pressure but a preferential development of properties caused by the steel roll. This different supercalendering response imported a two-sidedness onto the loblolly sheet. A thorough investigation into the nature of furnish compressibility and supercalendering theory should result in a better understanding of the properties developed by an uncoated paper.

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INTRODUCTION

The manufacture of highly supercalendered, uncoated paper for rotogravure printing is one of the growing markets in the paper industry. These types of papers are used for newspaper supplements, newspaper advertising inserts, and weekly magazines. They are also making inroads into the mail order catalog business. Some of the basic gravure printing problems associated with these papers are:

.dot-skip
.opacity
.poor stiffness
.press runnability

One of the re-occurring problems with uncoated supercalendered papers is dot-skip. Dot-skip results in print image unevenness or speckle. The paper properties which affect dot-skip are:

.smoothness
.compressibility
.surface absorbency

For this paper market to show continued growth, the papermaker will have to improve the quality of paper it produces for the rotogravure printing process. This study made a comparison of the surface and printing qualities of papers made from two different furnishes which were subjected to varying supercalendering conditions. This comparison was done to gain a better understanding of the paper quality produced by the varying conditions.

THEORETICAL DISCUSSION

Rotogravure Printing

In rotogravure printing, there must be good contact between the paper and the low viscosity ink in the engraved cells of the gravure cylinder, otherwise there will be no transfer of ink to the paper surface. Where no ink is transferred, there will be a missing halftone dot in the printed pattern resulting in an uneven, speckled image (1). A paper with a very high surface finish is required to reduce dot-skip. But , it is well known that an increased degree of smoothness and gloss do not necessarily give improved gravure printability. The paper surface is also compressible, and this surface compressibility plays an important role in how the paper will behave in the printing nip (2).

Calendering

To achieve the desired surface properties for the rotogravure printing process, some type of calendering must be used on the paper. The purpose of calendering is to develop a smooth surface finish. While producing a smoother finish, bulk is reduced proportionately. This reduction in bulk has an adverse affect upon the compressibility and absorbtivity of the sheet and thus it is desired to keep it to a minimum.

Work done by R.H. Crotogino (3) showed that the on-machine calender had definite limitations in the manufacture of high-grade newsprint for

rotogravure printing. He did printing and surface testing of papers produced using conventional on-machine calenders and supercalenders. The newsprint that was supercalendered had a glossier, smoother surface finish which required less ink and resulted in a lower print-through, at any given bulk.

To prepare uncoated paper for the gravure printing process using the machine calender, severe thickness reduction is required. This extreme reduction in thickness causes the small-scale basis weight variations (formation) to be transformed into bulk and surface property variations. These variations are easily noticeable as mottle when the paper is calendered to very low bulk.

The difference between the two calendering operations lies in the fact that supercalendering utilizes a "soft roll" technique. Because of this, supercalenders tend to calender toward a constant bulk instead of a constant thickness. Hence, the small-scale basis weight fluctuations are transformed into thickness variations. the bulk and surface properties will therefore be more uniform resulting in a better rotogravure printable paper.

Furnish

Besides calendering technique utilized, the properties of surface roughness and sheet compressibility are also affected by pulp furnish.

Krenkel (4) showed that paper roughness was a strong function of bulk and that this relationship changed with furnish. In a given calendering operation it has been found that it is more difficult to achieve a sheet of a given smoothness with the less compressible furnish.

In work done by Bristow and Ekman (5) they showed a clear difference in surface compressibilities of sheets made from different pulps.

Fiber selection to obtain the highest quality paper properties is not always a prerequisite in the paper industry. One of the objectives of this study was to compare two different furnishes to see if careful fiber selection could assist in producing a good uncoated paper that had bulk smoothness, and compressibility. Eucalyptus pulp was chosen because of its increasing popularity as a furnish in the production of printing and writing papers in West Europe. The loblolly was chosen because it would offer a wide difference in pulp furnish characteristics to which the eucalyptus could be compared.

The other objective of this study was to examine the effects of the different supercalendering conditions of roll hardness differences in the calendering nip upon the derived sheet properties.

EXPERIMEMTAL PROCEDURE

Paper

100% loblolly and eucalyptus water-leaf hand sheets were made from dry lap that had been soaked for 72 hours prior to pulping in the Valley Beater. Both furnishes were refined to approximately the same Canadian Standard Freeness (CSF). The loblolly was refined to 300 CSF while the eucalyptus was refined to 315 CSF. Three gram handsheets were made using the Noble-and-Wood apparatus and all sheets were conditioned at 23 degrees celcius and 50% RH prior to supercalendering.

Supercalendering

The Western Michigan University (WMU) laboratory supercalender was used for this study. Both the loblolly and eucalyptus sheets were subjected to the same sets of supercalendering conditions. In all, five different sets of five handsheets from each furnish were tested differently. The five different conditions were:

1. uncalendered
2. one pass at 2000 pli/felt side to steel roll
3. three passes at 2000 pli/felt side to steel roll
4. one pass at 2000 pli/wire side to steel roll
5. three passes at 2000 pli/ wire side to steel roll

After supercalendering the sheets were conditioned again.

Testing

The physical tests carried out on the handsheets were:

.caliper
.Parker print smoothness
10 and 20 kgf/cm2
.75 degrees Hunter gloss
.Helio print

The next part of the testing, involved the cross-sectioning, mounting, and subsequent viewing of the Z-direction of the loblolly hand sheets with the aid of a scanning electron microscope (SEM). The test procedure for this method is given in Appendix I, taken from an earlier study I did involving the viewing of Z-direction fiber networks. This testing was done to see what effect the supercalendering operation had on the fiber network structure. Appendix II shows a copy of the micrographs obtained. The goal of this testing was to use the WMU image analyzer to quantify the fiber network structure according to its density distribution. In an earlier study done at the Finnish Institute (6), they used an image analyzer to determine the fiber wall area which was then converted into a density measurement. This part of the testing was not completed due to the fact that the micrographs obtained could not be quantified at the the present time using the WMU image analyzer.

RESULTS

The experimental results are shown in Table I and II together with the supercalendering conditions. Table I shows the average values of the wire side and felt side surface and printing properties. The results shown are the mean values obtained from measurements made on five sheets per sample (25 total). Helio was only measured once per sample for a total of five measurements. Table II gives separate values for the wire side and felt side of the paper properites.

TABLE I:

Paper properties obtained form different furnish and supercalendering conditions

Sample	Number of passes (2000pli)	Side to steel roll	Thickness um	basis weight g/m2	bulk cm2/g	pps um(10)	75 Hunter Gloss %	Helio print per 20
L	0	-	165	75.3	2.19	9.1	2.3	18
L	1	FS	98	75.1	1.31	5.2	9.5	-
L	1	WS	97	75.1	1.29	5.9	10.3	-
L	3	FS	91	75.1	1.21	5.2	12.7	57
L	3	WS	94	78.7	1.19	4.8	12.5	51
U	0	-	205	77.1	2.66	7.8	2.2	111
U	1	FS	96	77.3	1.24	3.4	10.6	-
U	1	WS	96	77.6	1.24	3.4	10.7	-
U	3	FS	88	76.7	1.15	2.9	14.5	485
U	3	WS	89	77.5	1.15	2.9	14.2	545

KEY:

L = lolbolly
E = eucalyptus
FS = felt side
WS = wire side

TABLE II

WS and FS paper properties obtained

Sample	number of passes (2000pli)	side to steel roll	Parker-Print(20) um		Parker-Print(10) um		75 Hunter Gloss %		Helio print per 20	
			WS	FS	WS	FS	WS	FS	WS	FS
L	0	-	8.1	8.2	9.1	9.2	1.6	3.0	27	9
L	1	FS	4.7	4.3	5.4	5.0	8.9	10.0	-	-
L	1	WS	4.5	5.5	5.1	6.6	11.0	9.6	-	-
L	3	FS	4.7	4.2	5.6	4.8	11.4	14.0	52	61
L	3	WS	3.8	4.5	4.3	5.4	13.5	11.5	63	20
U	0	-	6.9	6.3	8.1	7.5	1.8	2.6	80	142
U	1	FS	3.0	3.1	3.5	3.4	10.5	10.7	-	-
U	1	WS	3.0	3.0	3.5	3.4	10.2	11.1	-	-
U	3	FS	2.6	2.6	3.0	2.9	14.2	14.6	400	570
U	3	WS	2.6	2.7	2.9	3.0	14.2	14.1	780	310

KEY:

L = loblolly
U = eucalyptus
FS = felt side
WS = wire side

DISCUSSION

Effects of Furnish

Figure 1 shows the reduction in caliper as a function of the number of passes through the supercalender. The eucalyptus shows the expected trend of a higher reduction in caliper, 53% versus 40% for the loblolly, upon supercalendering. Both furnishes show that it becomes increasingly difficult to decrease caliper after the first pass.

The eucalyptus also developed a higher gloss and smoothness (Figure 2) as compared with the loblolly. While these results are expected of a hardwood, the rate at which these properties develop is much higher for the eucalyptus as compared to the loblolly at a given supercalendering condition. The tangent lines drawn on Figure 2 indicate this faster response by the steeper slope of the eucalyptus tangent line. This faster degree of response is emphasized even more in the Helio print graph (Figure 3). These results are consistent with the prior discussion in that a more compressible pulp (eucalyptus) will give a better response to a given calendering operation.

Parker Print Measurement/ Helio Test Correlation

The evaluation of uncoated papers for the rotogravure process is complicated by the fact that conventional dot-skip measurements are more difficult to measure on the uncoated surface (1). Therefore, many

Figure 1. Caliper

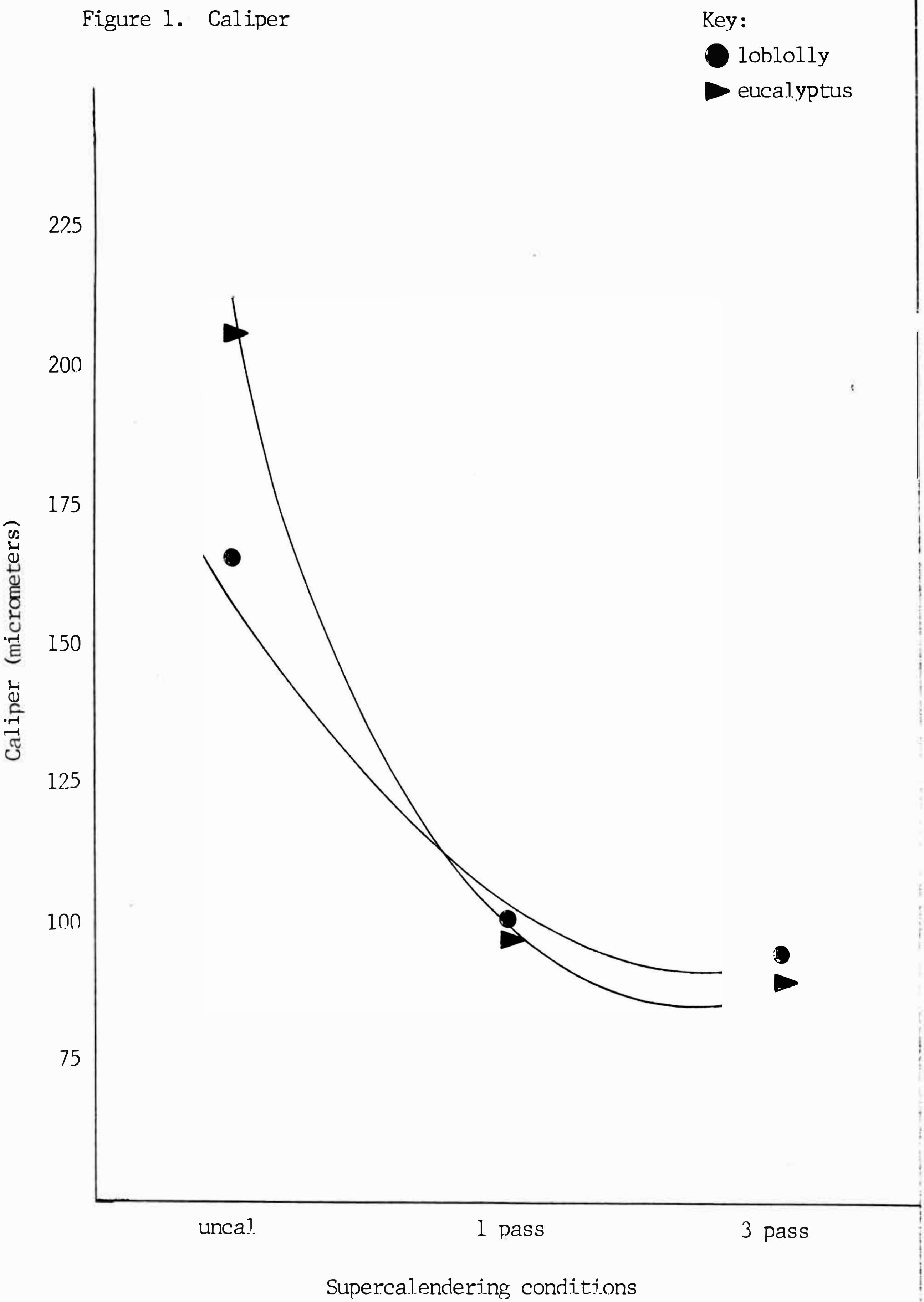


Figure 2. Parker Print at 10kgf/cm²

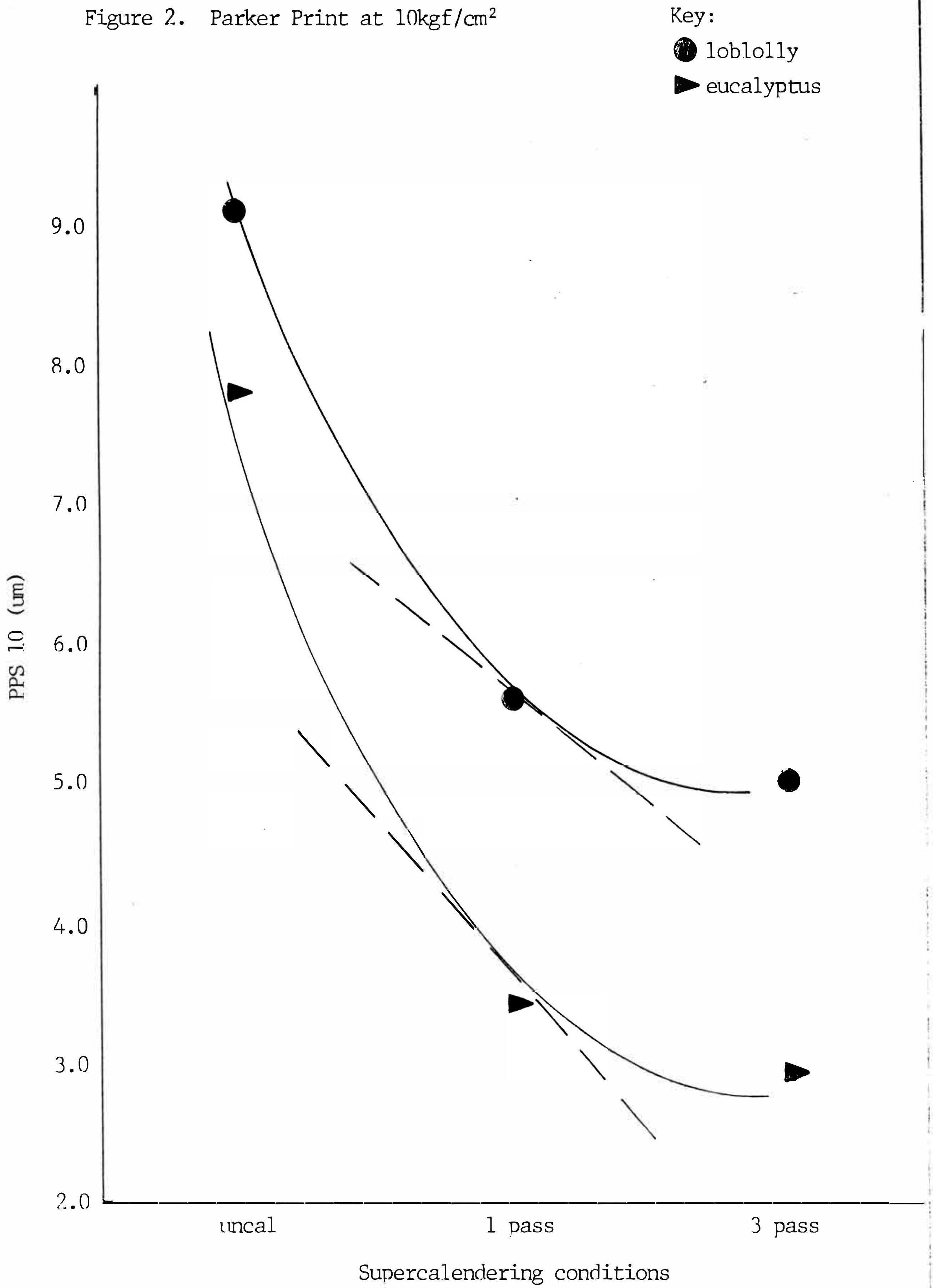
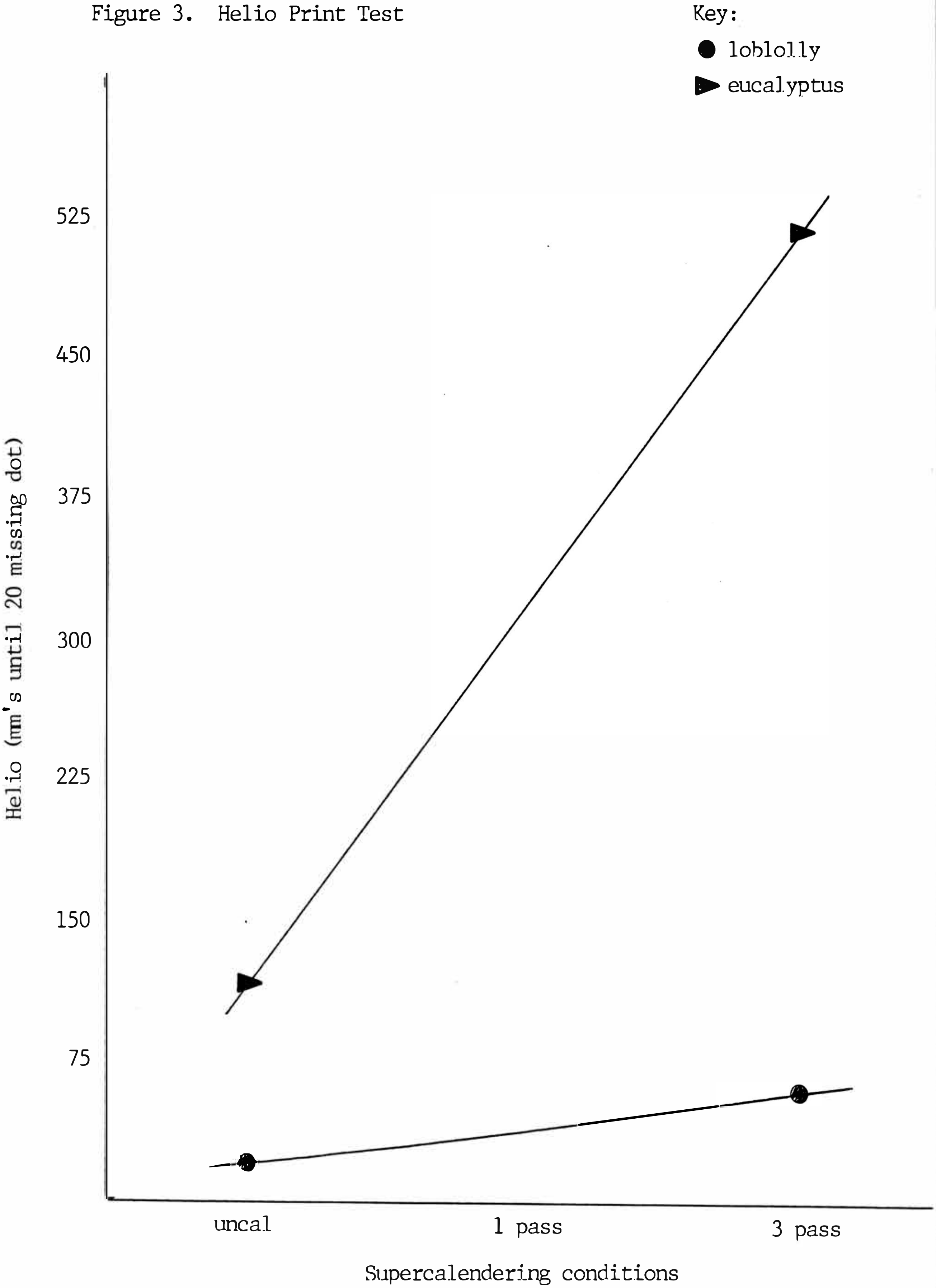


Figure 3. Helio Print Test



paper manufacturers use the Parker Print Surf to evaluate the rotogravure printability of their paper. Figure 4 shows the correlation between PPS and Helio results for the loblolly furnish. The difficulty in evaluating these papers is pointed out by the negative correlation received by the papers tested on the side of the supercalender filled roll application.

An explanation for this inconsistency is the problems encountered counting the skipped dots on an uncoated paper. Figure 5 shows the expected PPS/Helio correlation. Note the greater increase in the Helio test on the side of the sheets tested by the steel roll. Figure 6 shows the different gravure printability of the two different furnishes. It can be seen from this graph that the PPS/Helio relationship will probably be different for different furnishes.

Effects of Supercalender Rolls

The supercalendering variables are the steel roll application versus the filled roll application. As shown earlier (figure 5), this difference caused a significant change in the PPS/Helio test correlation between the two applications. To show (or not to show) the preferential treatment of the steel roll to the surface properties, the ratio of the wire side to the felt side as a function of bulk was graphed. Figures 7 and 8 show the PPS roughness ratio and gloss ratio respectively. For the less compressible loblolly furnish, the trend of increased smoothness and gloss is seen on

Figure 4. PPS/Helio correlation: Loblolly sheets

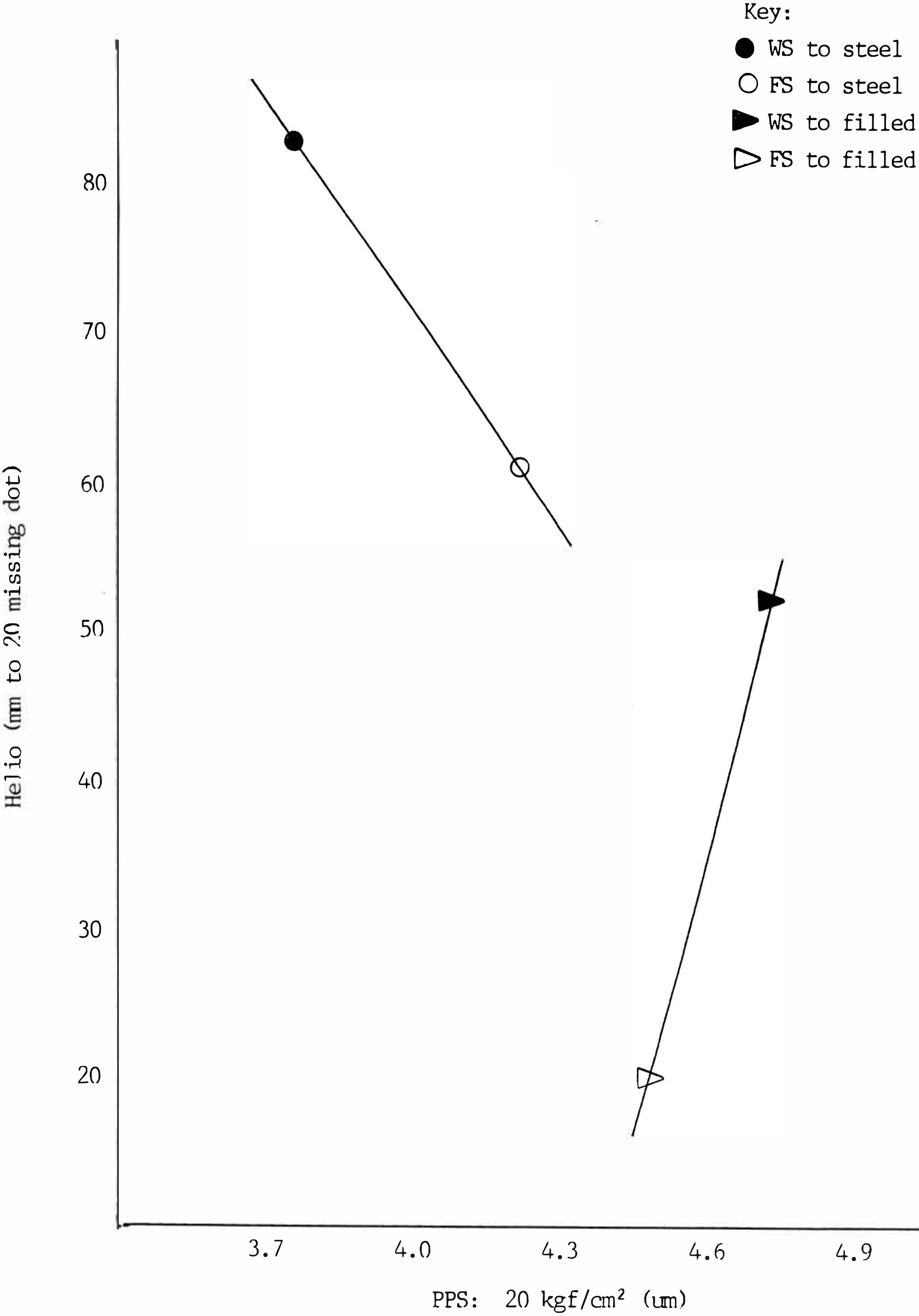


Figure 5. PPS/Helio correlation: eucalyptus sheets

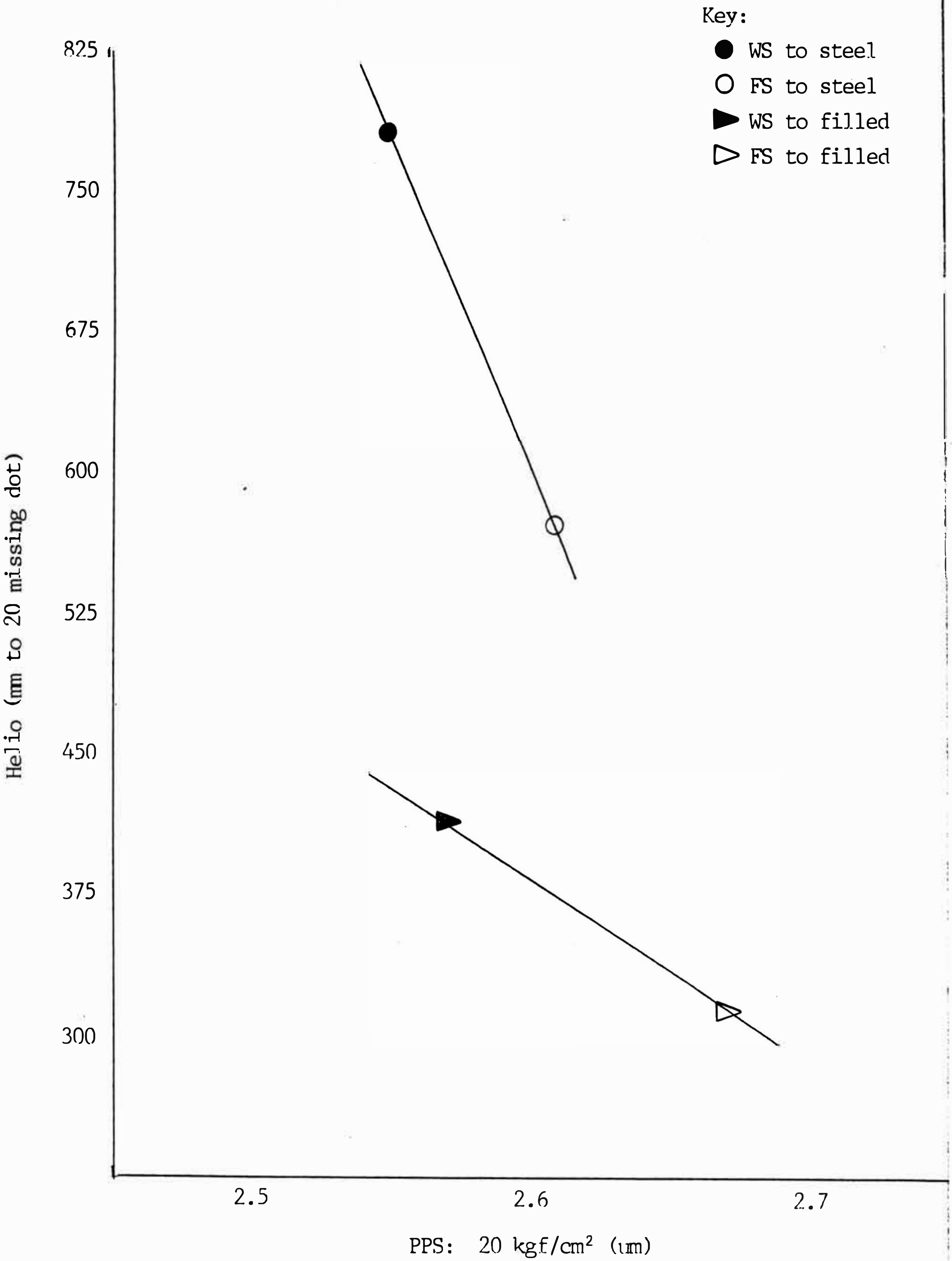
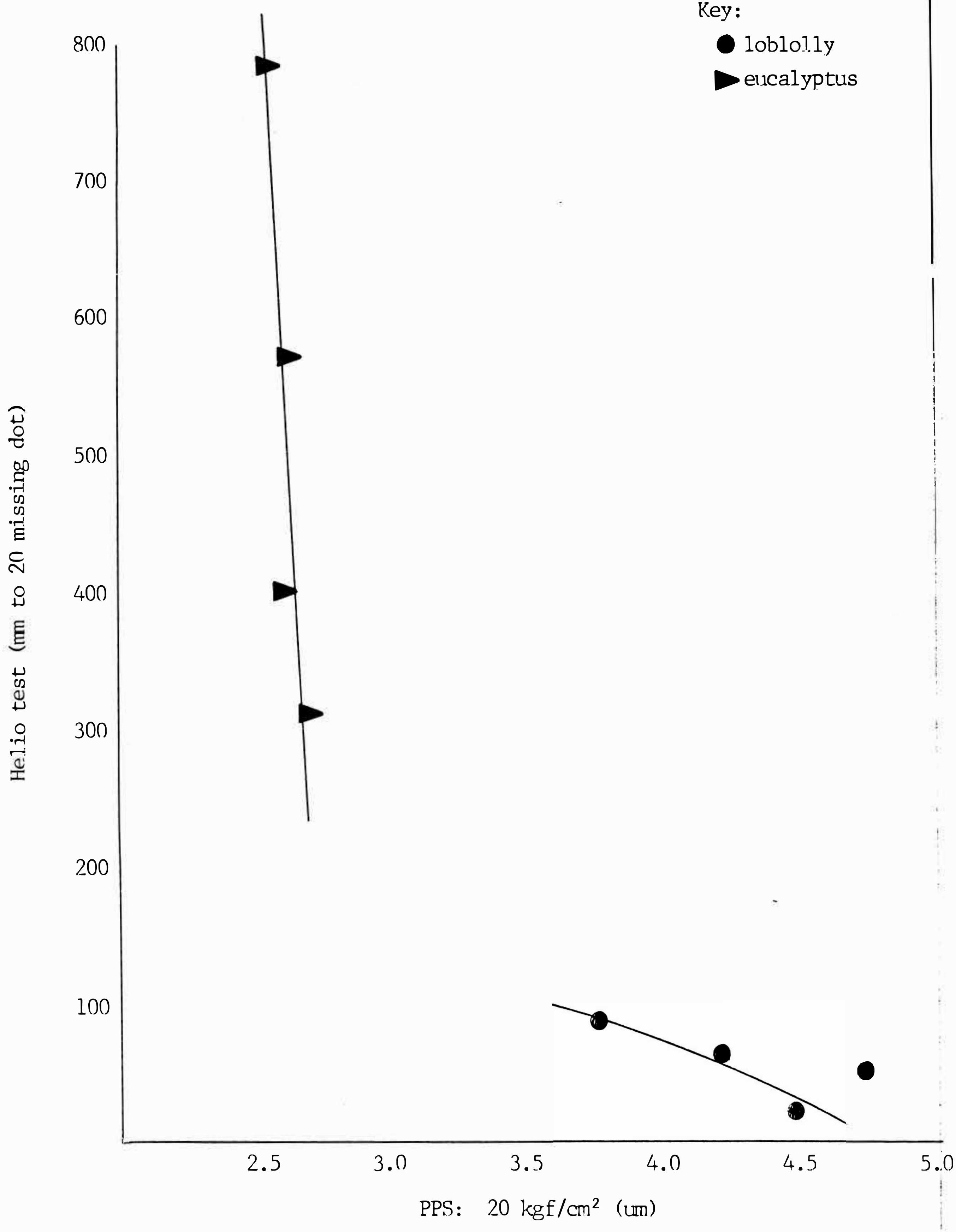


Figure 6: PPS/Helio Test Comparison of Furnishes



the side of the steel roll application. The eucalyptus reaction to the differing rolls is not varied. The roughness and gloss ratios are grouped together not showing a preference for either roll surface. One possible explanation of these results is that the smoother, glossier steel roll replicates its surface against the less compressible loblolly pulp. While, due to the high degree of compaction of the eucalyptus sheet, the steel roll surface has little effect on its derived surface properties. Contrary to this explanation is the increased printing properties achieved by the eucalyptus pulp upon steel roll application.

Figures 9 and 10 look at how the surface compressibility was affected by the different rolls. The measurement of surface compressibility was taken as the ratio of the roughness values under the two different measurement pressures used (10 and 20 kgf/cm2). Figure 9 shows a greater surface compressibility for the loblolly pine to the filled roll as compared to the steel roll. The eucalyptus shows this but only slightly. Figure 10 again shows a greater surface compressibility for the loblolly sheet tested against the filled roll. The eucalyptus sheet shows no difference.

From the above discussion, it is clear that the steel roll application when applied to the loblolly sheet results in smoother, glossier surface properties but at the expense of surface compressibility. One goal of this

Figure 7. Roughness Ratio (PPS 10) as a function of bulk

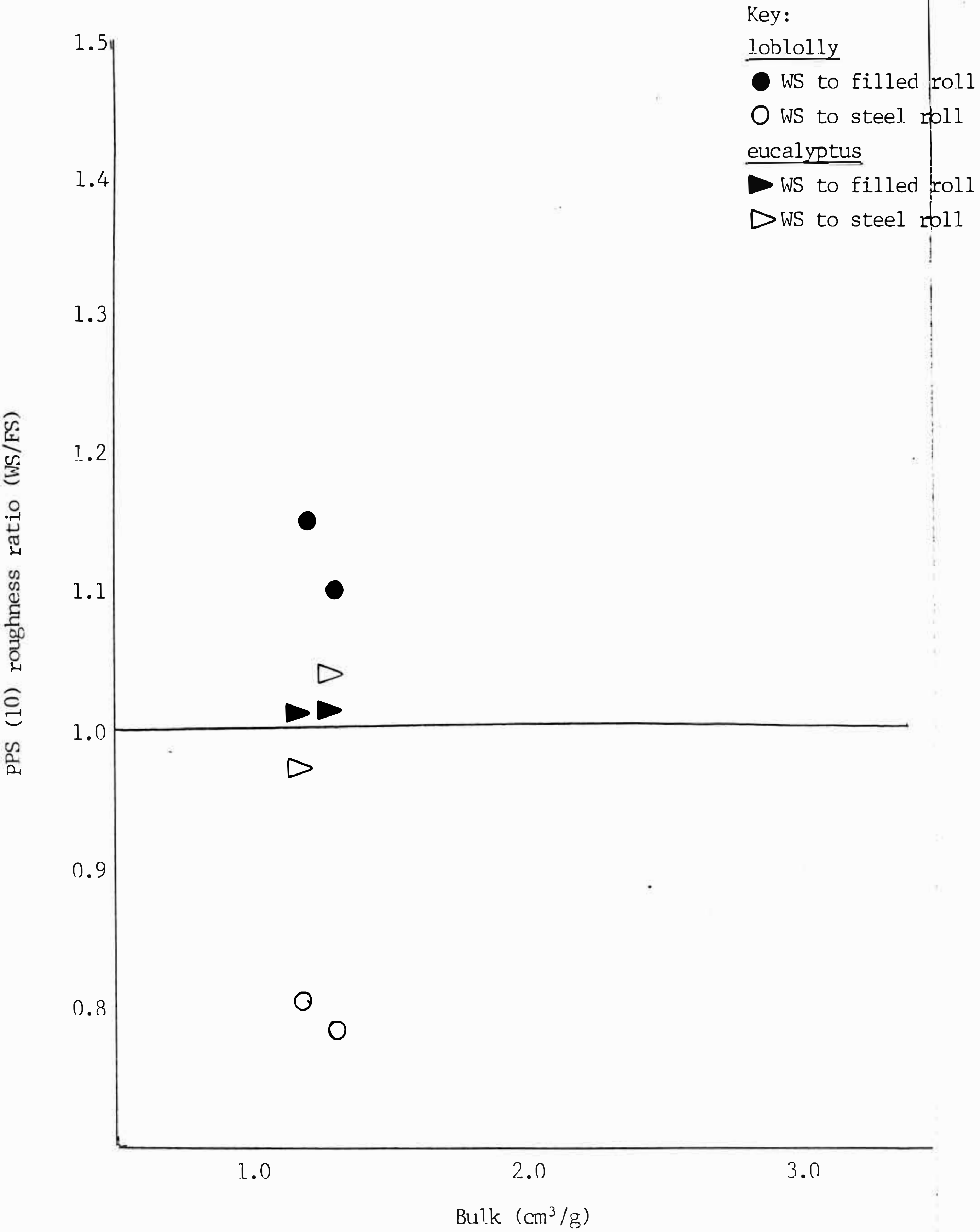


Figure 8. Gloss Ratio as a function of bulk

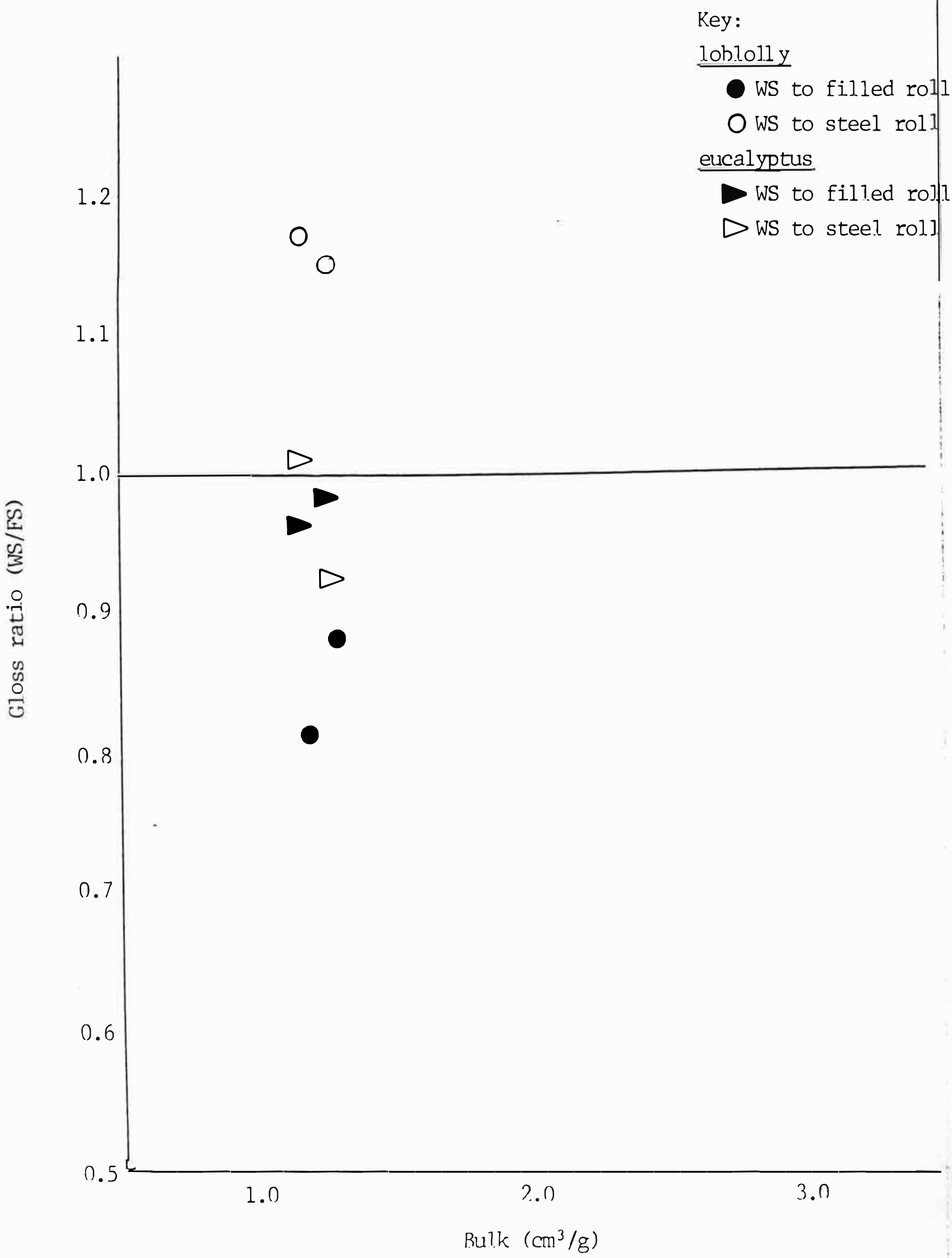


Figure 9. Wire Side Surface Compressibility as a function of bulk

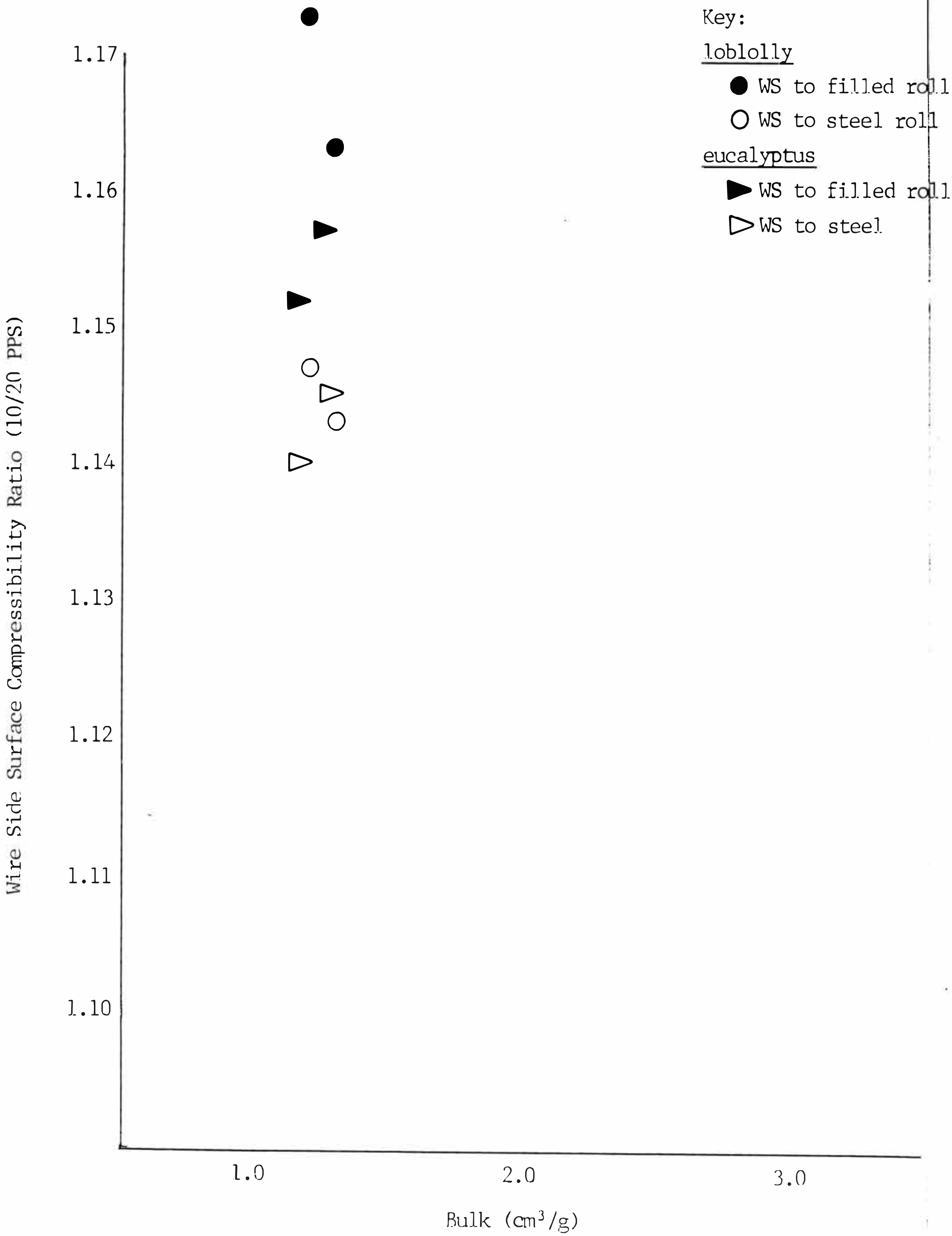
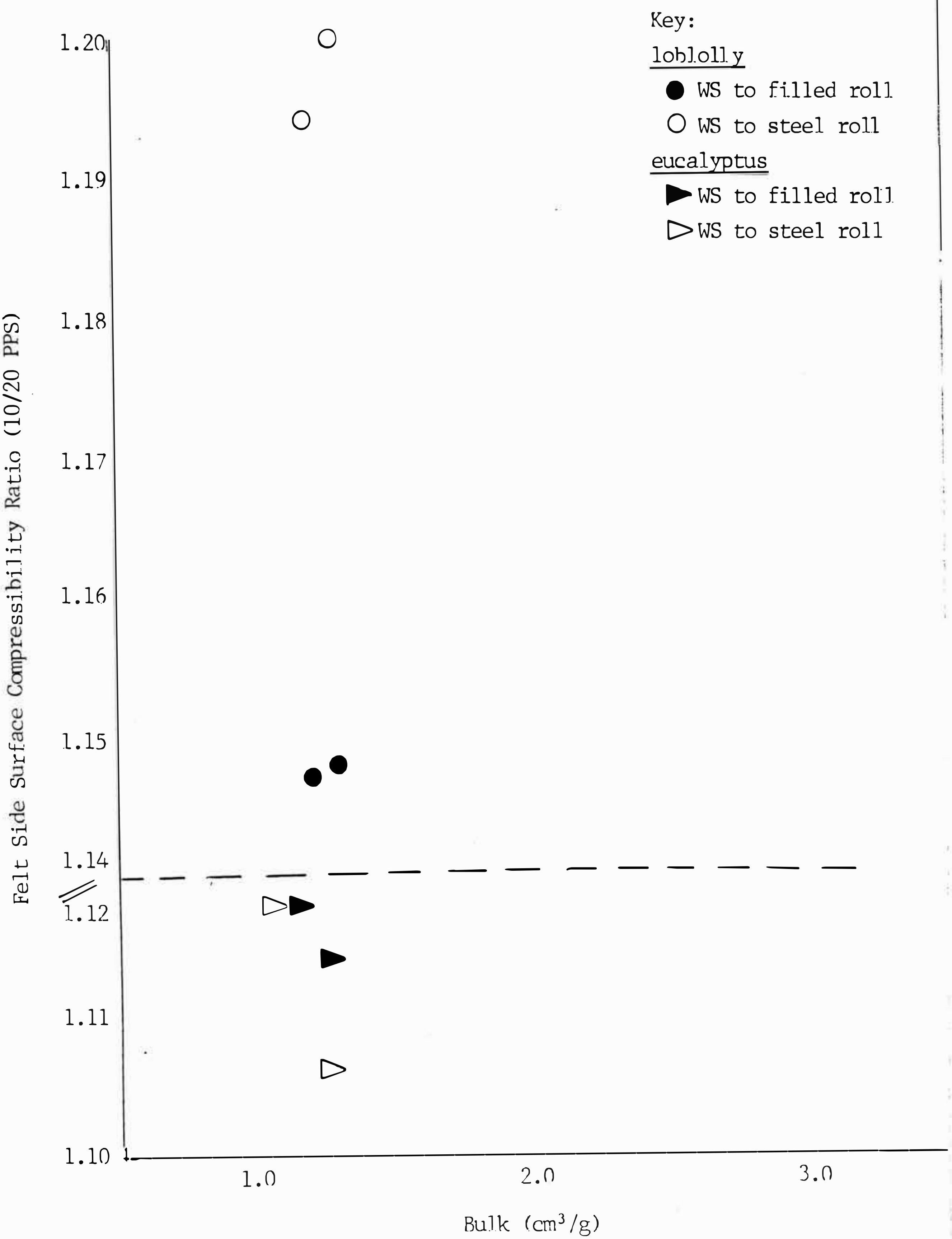


Figure 10. Felt Side Surface Compressibility as a function of bulk



study was to examine the effects of supercalendering nip pressure upon the fiber network. These results may indicate some fiber densification at the surface of the harder, steel roll. The denser surface would result in a glossier, smoother sheet with less surface compressibility. One possible cause for a density distribution difference across the Z-direction could be different shear forces induced in the nip. In work done by Brink (7), he found a biasing or non-cylic shear due to the driving torque. While the testing done here was far too few to constitute any statistical significance, the results may raise some interesting questions concerning supercalendering theory.

CONCLUSIONS

When the eucalyptus and loblolly sheets were compared, the differences in surface and printing properties were found to be quite large. The major difference between these two furnishes is in their fiber dimensions and thus their compaction in forming a sheet. The eucalyptus with its smaller fibers showed a greater compressibility and thus a greater response to any given calendering pressure application. Gloss, smoothness, and dot-skip were all superior for the eucalyptus sheet as compared to the loblolly sheet.

This study showed the separate relationships in sheet property development using different furnishes and supercalendering conditions. The compressible eucalyptus sheet showed a great response to nip pressure but roll surfaces had little effect on the derived sheet properties. The less compressible loblolly sheet showed less of a response to nip pressure but did show a preference to the steel roll supercalendering application. This preference imparted a two-sidedness property onto the loblolly sheets. A more thorough investigation into the compressible nature of pulp furnishes and the supercalendering conditions used on uncoated papers is likely to result in a better understanding of the paper quality produced.

RECOMMENDATIONS

This study also tried to examine the changes in the structure of fiber networks in paper caused by supercalendering. While the visual analysis was unsuccessful, the physical test results were interesting. The results received from the loblolly pine showed greater surface finish properties with a less compressible surface upon steel roll application. While these results may be inconclusive, I hope they raise some questions concerning supercalendering theory. Does the supercalendering action cause the substrate to flow? If so, is this flow uniform when rolls of different hardness are used in a calendering nip? I can see the area of supercalendering theory receiving more testing and experimentation to expand upon the current theories and find out more about the gray areas which do exist.

LITERATURE CITED

1. Dunfield, L.G., McDonald, J.D., Gratton, M.F., and Crotogino, R.H., Journal of Pulp and Paper Science 12 (2): J 31 (1986).

2. Bristow, J.A., Svensk papperstidning 85 (7): R 129 (1982).

3. Crotogino, R.H., Tappi 63 (11): 101 (1980).

4. Krenkel, B., Wochenblatt for Papierfabrilcation 104 (17): 621 (1976).

5. Bristow, J.A., and Ekman, H., Tappi 64 (10): 115 (1981).

6. Szikla, Z., and Paulapuro, H., Transaction of International Paper Physics Conference, Quebec, Canada. p. 113 (1987).

7. Brink, R., "Instrumentation for Roller Nip Studies", TAGA Proceedings, p. 103f (1963).

APPENDIX I

Test Procedure for Cross-Sectioning and Mounting of Paper Samples for SEM

I. Materials needed

*Liquid Nitrogen

*Styrofoam block with a well cut out of it (for the liquid N_2)

*razor blade (for best results, a new razor blade should be used for each cut)

*razor blade holder - a paint scrapper handle was used

*protective gloves and eye shield

*a metal plate - a 1½"x3" brass piece was used

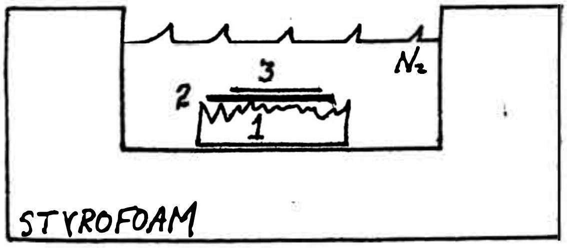
*a sponge - the metal plate was placed on top of the sponge, even though the N_2 dries out the sponge, it allowed some "give" which made shearing the sample easier

*tweezers, for removing and mounting of sheared sample

*double stick tape and carbon rods for the mounting of the paper samples

Fig 1. SIDE VIEW

1. sponge
2. metal plate
3. paper sample



II. Technique

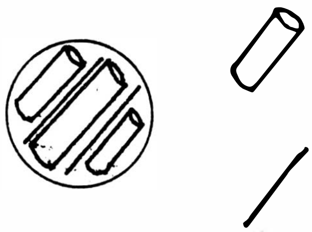
1. The paper sample width must not be wider than the SEM mount.
2. After the paper has been immersed in the liquid N_2 for a short period (>30 seconds), assemble the materials in the order shown in Fig 1.

   NEVER touch the liquid N_2 with your bare hand.

   Use the tweezers (forceps may also be used) to position materials as needed.
3. Using the tweezers to hold the paper sample in place on the metal piece, use your other hand to press straight down with the razor blade. The entire cross-section must be cut in one downward motion. Do not use a slicing cut (like a scissors) or results similiar to CT(2-20-87)2 on page 1 will result.

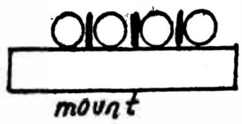
III. SEM Mounting

Fig 2. TOP VIEW



- carbon rods
- paper sample

SIDE VIEW



- carbon rods
- paper sample

mount

1. The carbon rods are used to hold paper samples upright so that the z-direction can be readily viewed. Carbon rods especially for this purpose are now available in the Paper Department. At the time of this study they were not available so the thickest pencil lead (200HB) available at the bookstore was used.
2. Before the paper is sheared, double stick tape should be applied to a SEM mount and one carbon rod put into place.
3. After a sample has been cut, use the tweezers to place the paper sample perpendicular to the mount. Then place another carbon rod directly on its other side to hold the sample upright (fig 2). 3 samples are appropriate for each mount.

IV. After the mount is ready, follow standard SEM instructions for preparing the mount for SEM viewing.

Appendix II

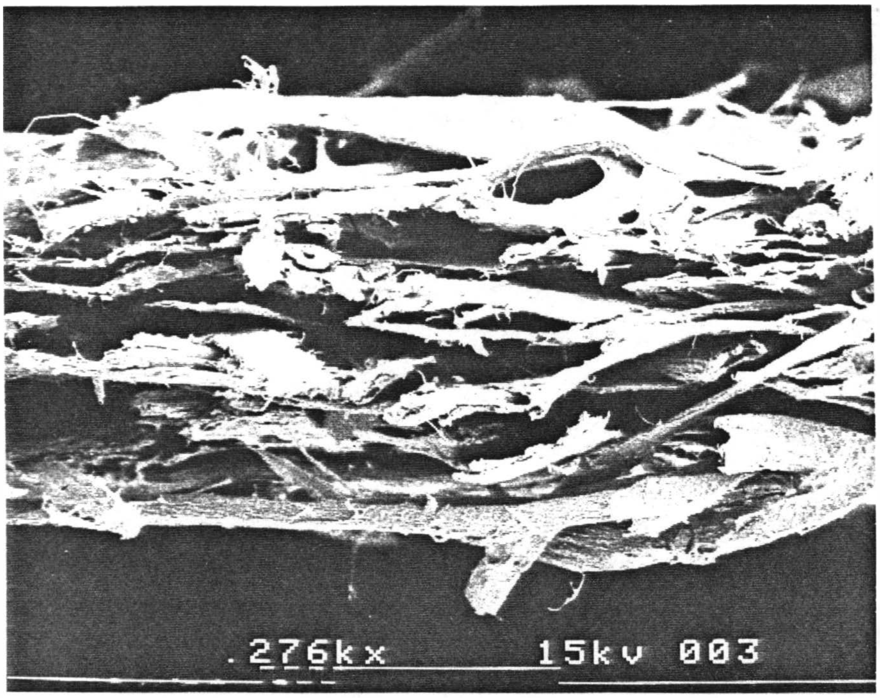
rection micrographs
oblolly handsheets

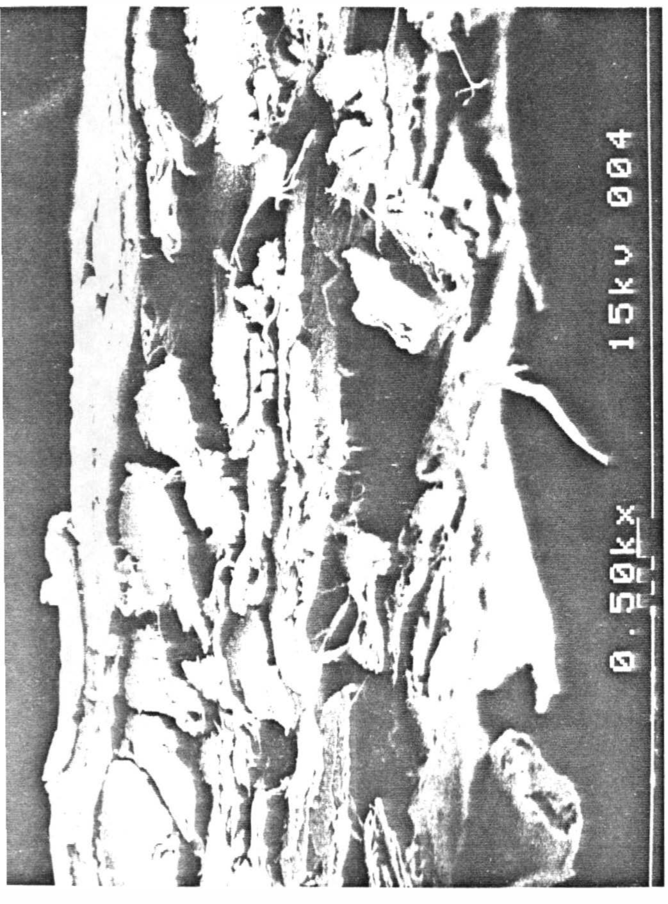
uncal

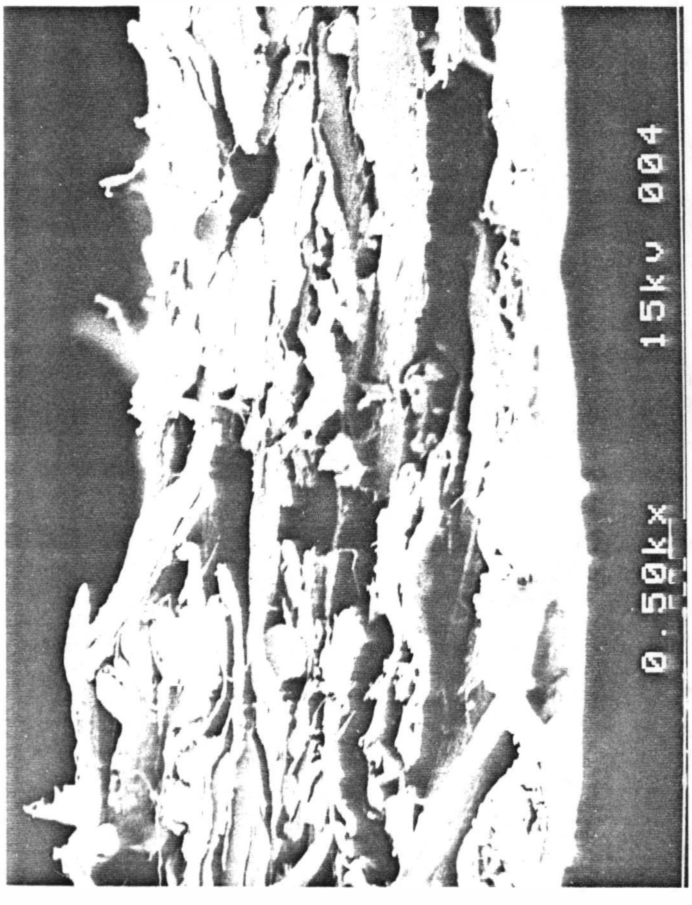
WS to filled roll

WS to steel roll

1







2.