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Use of Hot-Soft Calendering to Increase Gloss and Smoothness of Light Weight Coated Paper (LWC)

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TABLE OF CONTENTS

Abstract . . . . Pg 3

Acknowledgements . . . . Pg 4

Introduction . . . . Pg 5

Theoretical Background . . . . Pg 5

- Calendering . . . . Pg 5
- Supercalendering . . . . Pg 7
- Hot-Soft Calendering . . . . Pg 8

Experimental Design . . . . Pg 10

Data-Discussion . . . . Pg 13

Conclusions . . . . Pg 17

References . . . . Pg 20

Appendix I . . . . Pg 21

- Table I . . . . Pg 21
- Table II . . . . Pg 22
- Table III . . . . Pg 23
- Table IV . . . . Pg 24

Appendix II . . . . Pg 25

ABSTRACT

The purpose of this exercise was to investigate the use of Hot-Soft calendering as a means of pre-treatment for lightweight coated grades. The hot-soft calendering was performed at three temperatures and pressures to give nine test groups. These groups, along with one non-treated sample, were coated with the same coating and under the same conditions. Testing was performed on the uncoated base stock, the coated paper, and the coated paper after supercalendering.

The results showed that the hot-soft calendering, prior to coating, was beneficial to gloss only at higher temperatures and pressures. At lower temperatures and pressures, no significant change was seen. Smoothness levels, of the base stock and the coated paper, were increased with the use of hot-soft calendering. The pre-treated paper, after coating and supercalendering, was less smooth than the non pre-treated base stock.

ACKNOWLEDGEMENTS

The paper used in this thesis project was donated by Mead Paper in Escanaba, Michigan. Mead also donated the freight to ship the paper from Escanaba to Appleton, Wisconsin.

All hot-soft calendering was performed on a pilot calender at Valmet's facilities in Appleton, Wisconsin.

INTRODUCTION

The objective of this thesis project is to develop data that may make light weight coated (LWC) groundwood sheets more competitive with the coated wood-free sheets. By using hot-soft calendering as a pre-treatment to the coating process, it may be possible to produce a sheet that is both smoother and higher in gloss.

The ability to produce a low cost, high quality product is important to the prosperity and growth of a company. By using the hot-soft calendering process, the manufacturer should be able to use a lower cost substrate while producing the same quality product.

THEORETICAL BACKGROUND

Calendering

The term calendering, in its simplest form, means pressing with a roll.(1) There are many different types of calendering; machine calendering, supercalendering, and hot-soft or soft calendering. The effectiveness of a calendering operation depends on two factors: temperature and pressure.(2) When discussing any type of calendering, one must consider these variables.

The first type of calendering to be discussed will be machine calendering (MC). This type of calendering is performed as an integral part of the paper machine and will consist of between two to eight steel rolls in a stack. The primary function is caliper control, and also,to increase smoothness and gloss.(1)

The majority of machine calendars have both temperature and

pressure control. Surface temperatures of the steel rolls are controlled by a variety of methods. Steam may be applied directly to the surface of the rolls, or it may be injected into the roll as in a dryer can.(1) Usually, only one or two of the rolls in a calender stack are heated. This limits the amount of control that can be achieved.

Machine calenders are used on line as a form of caliper control. They achieve caliper control through the compression of the sheet in the Z-direction. This treatment is not uniform. The highest pressure is put on the high basis weight areas while low basis weight areas receive less treatment.(8) This variation in basis weight, prior to calendering, creates density variations after calendering. These variations in density are seen as surface mottling.(9)

Variations in density pose another problem as well. The varying density of the paper will cause liquids to be absorbed nonuniformly.(3) This will cause print mottle on a printed sheet and will cause the coated sheet to appear mottled.

As the sheet is compressed, internal shear forces are exerted on the fibers. These shear forces can cause the cell wall to delaminate and reduce the strength of the paper. At the same time, the paper becomes more dense as the void volume is removed.(4)

As strength is lost, so is opacity and brightness. Both opacity and brightness are dependent on the diffusion of light which is reflected or transmitted by the paper. This diffusion takes place as light passes through materials with different

refractive indexes. The void volume in a paper helps to supply this difference in refractive index, and as the void volume is removed, both opacity and brightness will decrease.

Supercalendering

Supercalenders in the U.S. consist of nine to fourteen rolls.(5) These rolls alternate from steel to cotton filled soft rolls.(1) The use of cotton rolls creates a limitation on both speed and temperature of operations.(5) The slower speed of operation makes it necessary for supercalendering to be an off machine operation.

Unlike machine calenders, external heat is not added to supercalenders. However, heat is present due to the repeated compression and expansion of the cotton rolls.(5) Pressure can be controlled in a supercalender operation.

Supercalendering can be used to achieve the same surface properties that are accomplished by machine calenders without as great a loss of strength or optical properties. This is possible because the cotton rolls in a supercalender deform to the surface of the paper.(8) This allows for equal treatment of the entire sheet and will produce paper of a more uniform density.(7)

As mentioned earlier, density of the sheet will affect its appearance. A more uniform density will reduce or eliminate the mottled appearance of a printed or coated sheet.

An important parameter affecting the effectiveness of calendering is roll temperature. Supercalendering, which gives good surface qualities, limits the amount of heat that can be used

due to the cotton rolls. High temperatures soften the paper web allowing it to more readily respond to the mechanical calendering action.(7) Cotton rolls in supercalenders do not allow these high temperatures to be used.

Hot-Soft Calendering

Hot-soft calendering, or soft calendering as it will be referred to from here on, differs from supercalendering in two ways. First, it uses epoxy rolls instead of cotton rolls. This allows for greater temperatures and speeds. Secondly, soft calendering utilizes temperatures in excess of 200 °C. This decreases the number of nips required to obtain comparable surface qualities.

Soft calenders operate in a fashion similar to supercalenders. The epoxy rolls of a soft calender deform to the surface of the paper. This allows for uniform treatment of the paper. However, using both high temperatures and soft rolls allows for a more gentle calendering action while decreasing the number of required nips.

The use of high temperatures in the soft calendering process heats the surface of the sheet and makes it more susceptible to the mechanical action of calendering. This leaves the center portion of the sheet intact and prevents the damaging delamination of fiber walls which causes reduction in sheet strength.(9)

Brightness and opacity must also be considered when looking at the application connected with coating operations. Hot-soft calendering preserves opacity and brightness at pressure levels

higher than those achieved with supercalendering.(2) This is due to the fact that the sheet is not compacted to the same degree as super or machine calendering. This preserves the void volume which is important to reflectance.

When looking at coated paper, it is important to remember that coating will not hide raw stock defects, but will in fact accentuate them.(10) For this reason, it is important to every coating operation, especially a light weight coated grade, that the base stock be of the highest quality.

The final properties of the coated sheet to be looked at are gloss and smoothness. The presence of these is dependent on the quality of the base stock to be coated. This is even truer for light weight coated due to the fact that only about 7 g/m^2 of coating is being applied per side.(10)

The basic idea behind coating is to apply a thin film of a pigmented coating. This will fill in the valleys of the sheet and give a smooth, uniform surface appearance. In order for the coating operation to run, the sheet needs to be as smooth as possible, have good strength, and have uniform absorbability.

The smoothness of the final coated sheet is dependent on three things: the condition of the base stock, the coating used, and the amount of supercalendering. For a light weight coated sheet, the one variable that can make the largest difference is the smoothness of the sheet prior to coating. Supercalendering of the sheet after the coating operation cannot rectify an uneven distribution of coating, and it has been found that extensive calendering of the

sheet prior to coating is detrimental also.

Conventional calendering could not be used in the past because it created a sheet of good smoothness, but at the cost of uniform density.(10) If the sheet does not have a uniform density, it will absorb or accept the coating differently in different areas. This will cause a splotchy appearance with a mottled effect for printed surfaces.

Gloss is more dependent on the type of pigment used than on sheet properties. However, if a poor sheet is to be coated, good gloss will not be achievable. The coating used will be discussed later.

In order for gloss to be achieved, there are two things that need to be accomplished. First, the base stock should be covered entirely. This means that the base sheet must be smooth. Secondly, the amount of binder used must be minimized. To minimize the binder used, it is important to have a base stock that has uniform porosity to absorb the coating.(10)

In the coating operation, it is important that the brightness and opacity of the base sheet be sufficient for the final product.(10) The use of soft calenders to achieve the proper smoothness and density uniformity will also ensure this.

The use of the soft calendering as a pre-treatment to coating is intended to increase the quality of the final coated sheet by improving the base stock. The soft calender is claimed to make the sheet smoother. This will ensure good coverage and promote an even distribution of the coating across the surface of the paper. The

soft calendering is also expected to give the sheet a more uniform density. This will provide a more uniformly absorbent surface for the coating.

EXPERIMENTAL DESIGN

The base stock used in this project was 54.7 g/m^2 ground-wood containing paper. It was an acid sheet with a filler content of 6% and had a moisture content of 3.5%. The rolls were calendered slightly for caliper control.

Phase one of the experiment was to soft calender the base stock. All calendering was performed at the pilot facilities of Valmet in Appleton, Wisconsin. There were to be 10 groups: one control group, which would be the untreated paper as it arrived, and nine test groups. The nine groups were run at three different temperatures and three different pressures.

In mill applications in Europe, where soft calenders are run to a greater extent than in the U.S., normal press loads and temperatures would be 170 kN/m (970 PLI) and 190°C (374°F).[3] These pressures and temperatures were used as medians in this experiment. The temperatures used were 284°F, 374°F, and 464°F. The pressures used were 750, 1250, and 1750 pli.

The rolls of paper were run on a 14 inch pilot calender at 2000 fpm. Only one nip was used. The epoxy rolls of the calender had a shore D hardness of 89.

The next step was coating preparation. The coating used in this experiment was an offset formulation. The formulation contained 60% delaminated clay and 40% #2 clay. These were

dispersed at 70% solids. Binders used were 4 parts penford gum starch and 10 parts Dow 620 latex. Dilution water was required to achieve a final coating solids of 62%. The formulation was mixed for 30 minutes and then stored in large plastic jugs.

The next step was the actual coating operation. To achieve the required target coat weight of 7 g/m^2 per side, three blade pressures were used on the Keegan coater in Western Michigan University's coating lab. Blade pressures of 1000, 500, and 200 g were used.

After the coating operation was carried out and the rolls were slabbed, coat weight circles were cut. Of the three blade pressures for each run, the samples with a coat weight nearest to 7 g/m^2 were used. A table of coat weights is given in Appendix II.

Testing was performed on the coated paper both prior to and after supercalendering. Supercalendering was performed on the laboratory supercalender at Western Michigan University. The supercalendering was done at 30 psi with no addition of heat. Samples were fed through randomly so that each sheet was treated with four nips. Prior to calendering, the machine was allowed to warm up for 45 minutes.

The samples with the proper coat weights were then tested. Tests were also run on the uncoated base stock to keep track of the changes taking place due to the calendering operation. Prior to all testing, samples were stored in the conditioning room at 73 ^{o}F and 50% relative humidity.

For the uncoated sheet, opacity, brightness, hunter gloss, and

parker print surf tests were performed. The same tests were run on both the supercalendered and the unsupercalendered coated paper. These results are available in appendix I .

For the data presented in graph form t-tests were used to test for statistical significance.(11) All comparisons were made using only the significant values.

DATA and DISCUSSION

Brightness and opacity tests were run on all samples. The results for these tests can be found in Tables I and II in Appendix I. As with the conventional calendering process, both of these values will tend to decrease as calendering is increased. The results obtained in this experiment support this axiom.

Literature suggests that the amount of opacity and brightness lost will be lower with the hot-soft process than with conventional machine calendering. However, with this project, conventional steel to steel calendering was not done, so comparisons are not possible.

Presentation of the smoothness and gloss data will be done in three parts; starting with the base stock and ending with the supercalendered coated sheets.

Figures 1 and 2 show the gloss and roughness results of the base stock. As either temperature or pressure is increased the gloss of the sheet is increased and the roughness is decreased.

A reason for this is that as the temperature is increased, the surface becomes more pliable and will thus be more receptive to constant mechanical force. This will decrease the micro roughness,

which is seen as an increase in gloss, as well as the macro roughness or parker print.

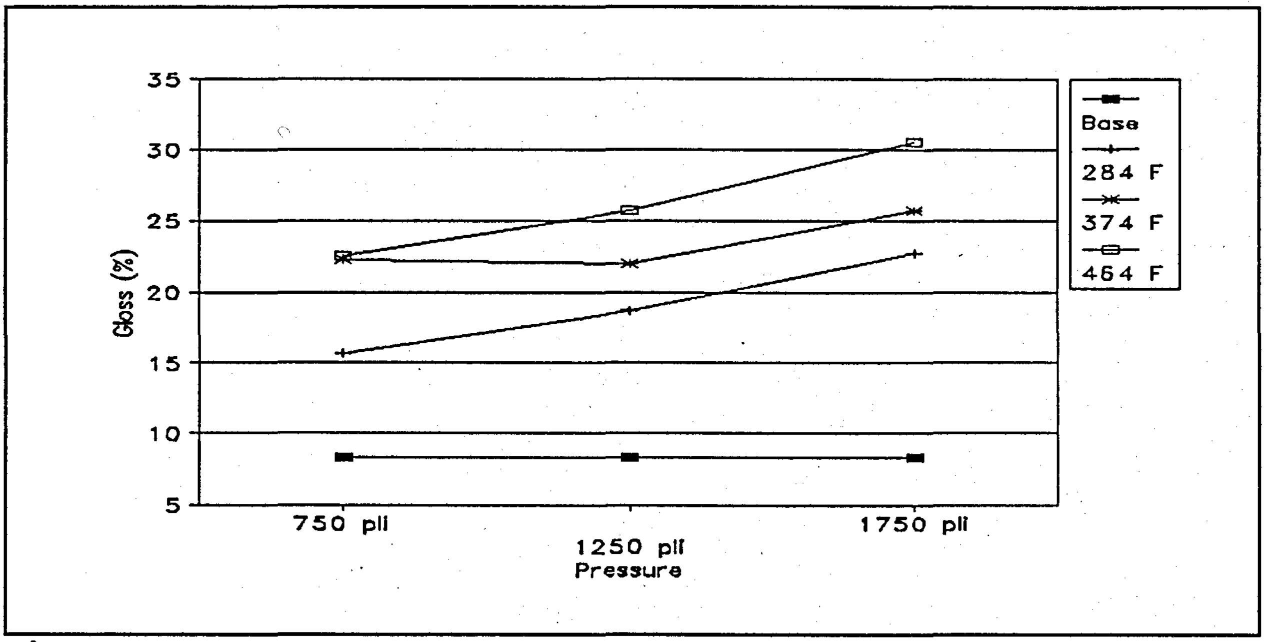

Figure 1. The effects of temperature and pressure on the gloss of the uncoated base stock.

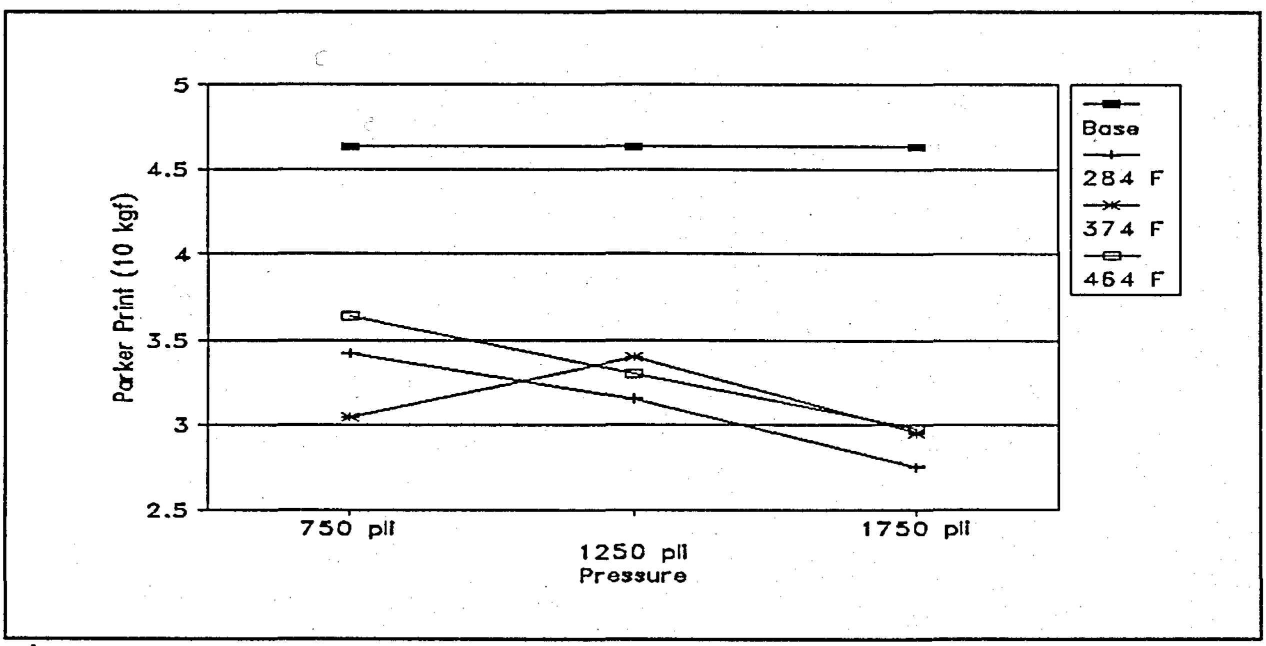

Figure 2. The effects of temperature and pressure on the roughness of the uncoated base stock.

As pressure is increased at constant temperature, the same

results are seen. The gloss is improved while the roughness is decreased.

These results for the coated sheets were also expected because of similar results for both temperature and pressure changes. The only unexpected results were those of the supercalendered sheets.

Using a 90% confidence level, it was found that the first two pressures at 284°F were statistically the same. However, all other data points on the supercalendered gloss graphs were significantly different. Investigation of the gloss graphs shows that the improved gloss of the base stock is carried over after coating.(Fig 3) However, when these samples are supercalendered, the lower end of temperature, and pressure in one sample, produces a lower gloss than the untreated basestock.(Fig 4)

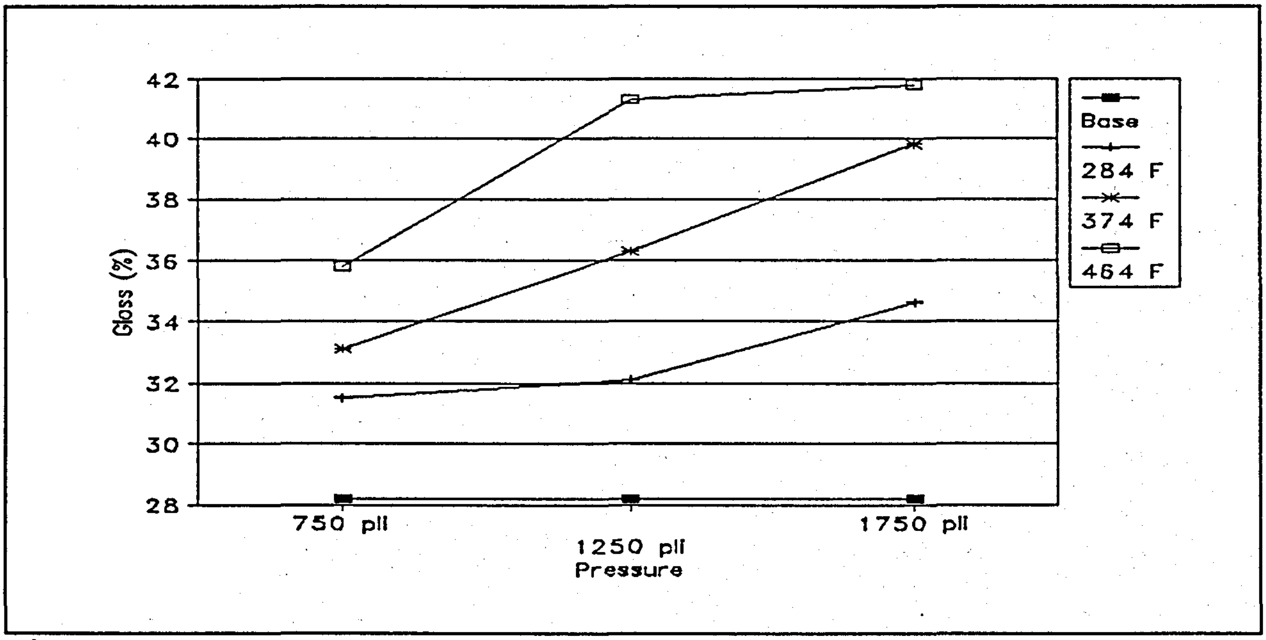

Figure 3. The effects of temperature and pressure on the gloss of the coated samples.

A possible reason for this is that at the lower conditioning levels, there is still a nonuniform absorption of the coating onto

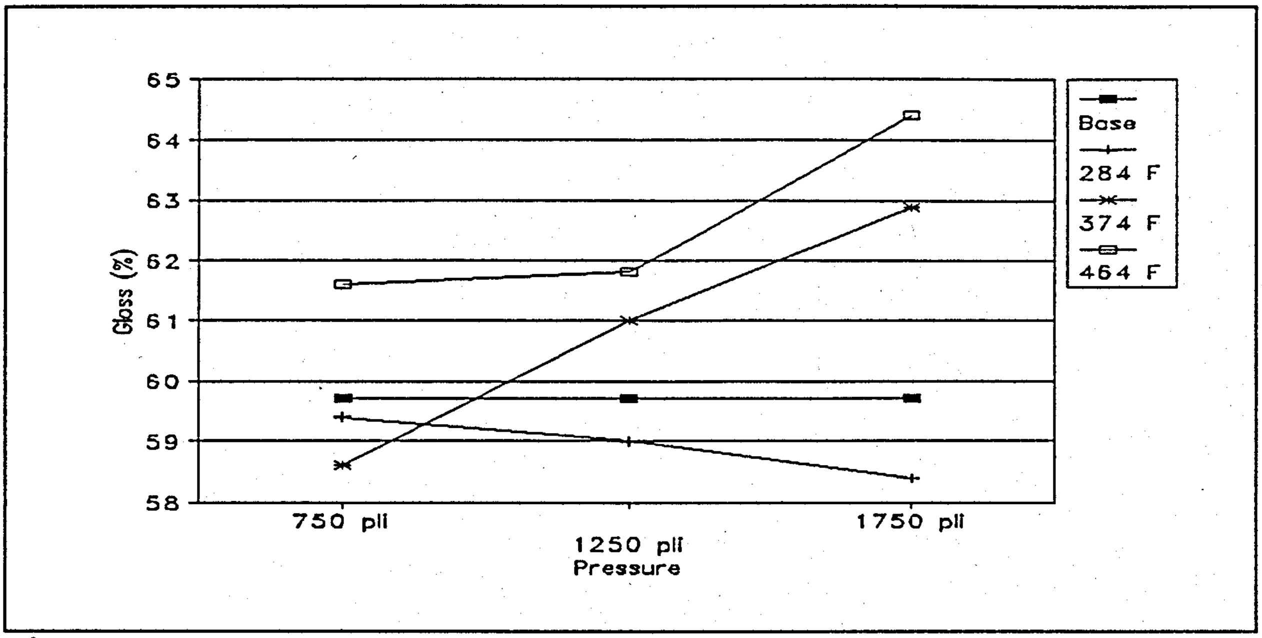

Figure 4. The effects of temperature and pressure on the gloss of the supercalendered sheets.

the surface of the paper. This would leave binder in different levels of the coating. According to Casey, supercalendering causes a repositioning and alignment of the coating.(10) This minor repositioning of the coating surface would expose the binder and decrease the micro smoothness. Gloss reduction, in this case, is caused by the decrease in micro smoothness.

In order for there to be uniform absorption of the coating, and thereby even distribution of binder, the surface of the sheet must be of equal or uniform density. This maybe the reason that the gloss is higher at the more extreme temperatures and pressures. In order to achieve uniform density, the sheet must be altered to the point of highest density. This may not be accomplished at the lower temperatures and pressures where the calendering action is less severe. Only as the conditions are increased will the density reach an even level where gloss improvements are seen.

Casey says that supercalendering compacts the coating layer.(10) This makes it more dense and gives it a smoother surface. When comparing the coated graphs with supercalendered graphs, this trend is seen. However, looking at the coated sheets, it is apparent that the untreated base stock is rougher than the treated samples.(Fig 5) After supercalendering, the untreated samples become less rough or more smooth than the pre-treated paper.(Fig 6) This trend was unexpected and needs to be explained.

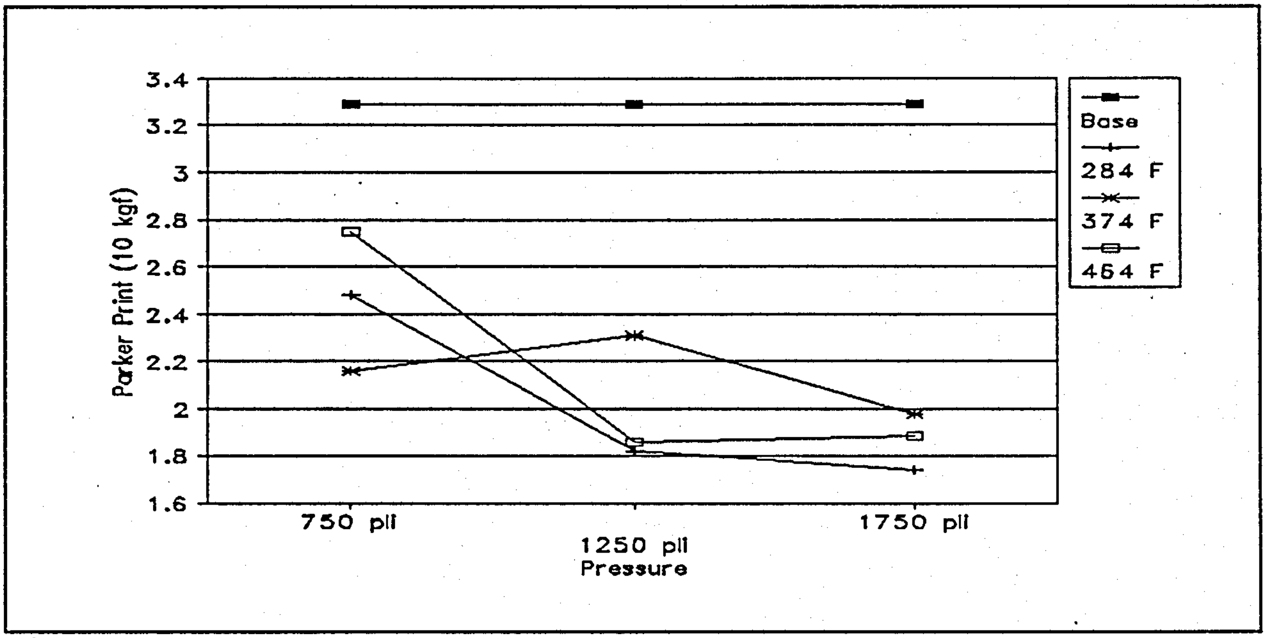

Figure 5. The effects of temperature and pressure on the roughness of the coated samples.

A possible explanation for this starts with the base stock. The untreated base stock is rougher than any of the soft calendered samples.(Fig 2) When coating is applied to this surface, a less uniform structure may be formed which leaves room for movement.

The higher smoothness of the soft calendered sheets carries over after coating. This may due to a more uniform coating layer being applied to the smoother base sheet. Supercalendering of this

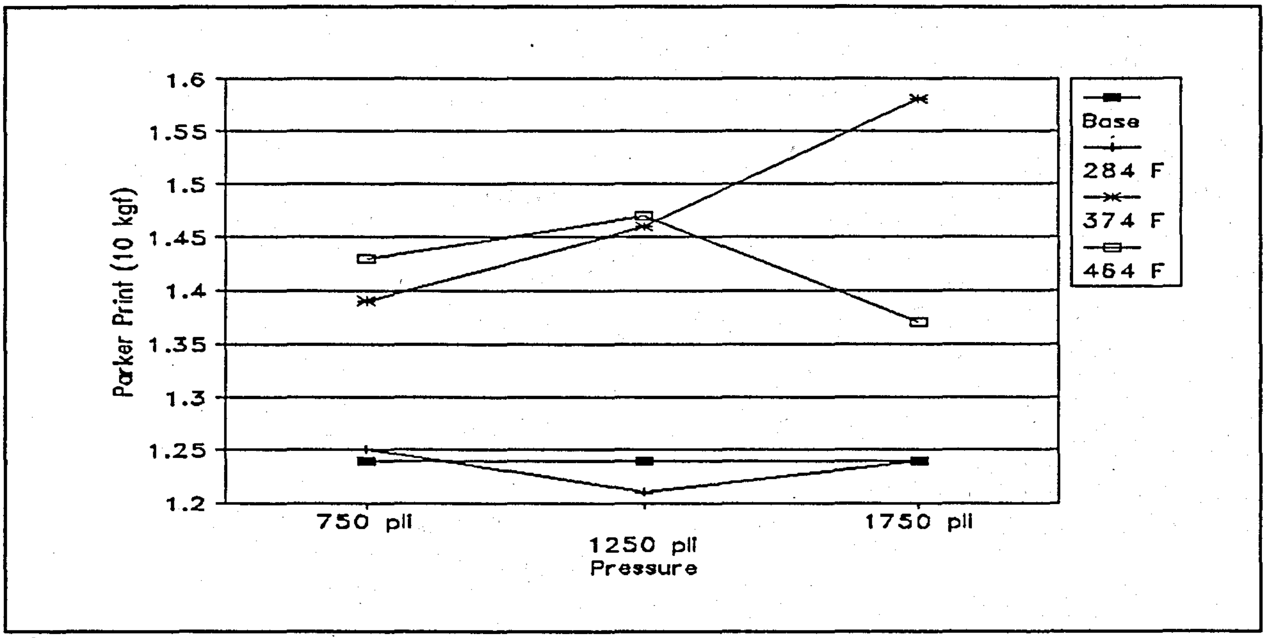

Figure 6. The effects of temperature and pressure on the roughness of the supercalendered samples.

sheet was expected to produce a sheet of higher smoothness than the non-soft calendered paper. This was not the case.

A possible reason for this is that if the coating layer is less structured, it will have the ability to be compressed into a smooth surface. The action of the supercalender will be maximized on these samples because they are more receptive to this action. The pre-treated sheets which may have a more structured layer will resist the supercalendering because there is less room for realignment of coating particles.

CONCLUSIONS

Hot-soft calendering, prior to a coating operation, will indeed affect the final properties. Since gloss and smoothness are not necessarily related, the amount of pre-treatment must be chosen carefully.

If higher gloss levels are required, soft calendering at high

temperatures and pressures is necessary. Selection of proper coating is also important. However, as gloss is improved, surface roughness of the sheet will be increased when compared to a non-treated sheet.

Soft calendering, prior to coating, was found to be detrimental to the smoothness after supercalendering. If supercalendering is normally not performed, pre-treatment would help increase smoothness levels.

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APPENDIX I

TABLE I

Brightness

											AVG	STD
CONTROL (Untreated)											AVG	STD
BASE:	73.2	73.9	73.7	73.5	73.8	73.7	73.5	73.5	73.5	73.5	73.6	0.189
COATED:	78.4	78.3	78.4	78.5	78.6	78.3	78.4	78.4	78.4	78.4	78.4	0.083
SUPERED:	76.8	77.0	77.0	77.0	77.3	77.3	76.9	77.2	77.3	76.8	77.1	0.191
1-A												
BASE:	73.4	73.1	72.9	73.1	73.2	73.0	73.3	73.8	73.3	73.1	73.2	0.240
COATED:	78.4	78.4	78.5	78.5	78.6	78.4	78.5	78.9	78.3	78.5	78.5	0.155
SUPERED:	77.0	77.5	77.4	77.3	77.2	77.1	77.5	77.4	77.3	76.9	77.3	0.196
1-B											AVG	STD
BASE:	73.3	73.0	72.8	72.8	72.7	73.4	72.6	73.0	72.4	72.7	72.9	0.293
COATED:	79.5	79.4	79.5	79.3	79.2	79.3	79.3	79.0	79.0	79.3	79.3	0.166
SUPERED:	77.6	77.3	77.6	77.2	77.8	77.7	77.7	77.9	76.9	76.9	77.5	0.344
1-C												
BASE:	72.3	72.4	72.7	72.2	72.6	72.9	72.2	72.4	72.2	72.3	72.4	0.227
COATED:	78.5	78.2	78.3	78.4	78.6	78.4	78.5	78.5	78.5	78.5	78.4	0.111
SUPERED:	77.8	78.0	78.0	77.9	77.7	78.0	78.0	77.7	77.6	77.7	77.8	0.150
2-A											AVG	STD
BASE:	72.7	72.4	72.4	72.8	72.5	72.4	72.5	72.5	72.6	72.2	72.5	0.161
COATED:	78.6	78.5	78.2	78.5	78.8	78.5	78.5	78.7	78.5	78.3	78.5	0.164
SUPERED:	76.9	77.0	76.9	77.0	77.1	77.3	77.0	77.0	76.8	76.7	77.0	0.155
2-B												
BASE:	72.1	72.2	72.4	72.3	72.0	72.1	72.2	72.2	72.0	72.2	72.2	0.119
COATED:	77.6	77.4	77.4	77.5	77.6	77.3	77.6	77.4	77.3	77.6	77.5	0.119
SUPERED:	76.3	76.3	76.4	76.3	76.1	76.3	76.0	76.0	76.1	76.2	76.2	0.134
2-C											AVG	STD
BASE:	72.1	72.1	72.1	72.5	72.1	72.1	72.2	72.1	72.2	72.1	72.2	0.120
COATED:	76.7	76.6	76.8	76.9	76.8	77.5	76.8	76.4	76.6	76.9	76.8	0.276
SUPERED:	75.3	75.6	76.0	75.4	75.4	75.2	75.2	75.1	75.0	75.3	75.4	0.269
3-A												
BASE:	72.6	72.7	72.6	72.6	72.6	72.7	72.6	72.5	72.4	72.1	72.5	0.169
COATED:	77.4	77.7	77.2	77.2	77.5	77.3	77.4	77.5	77.3	77.3	77.4	0.147
SUPERED:	76.1	75.6	76.0	75.8	75.6	76.0	75.9	75.9	75.9	75.9	75.9	0.155
3-B											AVG	STD
BASE:	72.6	72.7	72.3	72.3	72.3	72.4	72.4	72.3	72.4	72.4	72.4	0.130
COATED:	76.3	77.0	76.7	76.8	76.6	76.7	76.8	76.8	77.0	76.5	76.7	0.204
SUPERED:	75.4	75.4	75.4	75.8	75.1	75.4	75.2	75.6	75.6	75.3	75.4	0.194
3-C												
BASE:	71.7	71.9	72.0	71.8	71.9	71.7	71.8	72.2	71.7	71.9	71.9	0.150
COATED:	76.9	77.2	77.1	76.7	76.8	76.5	76.7	77.2	77.0	77.4	77.0	0.270
SUPERED:	75.7	75.8	75.5	76.1	75.7	75.0	75.6	75.5	75.3	75.7	75.6	0.280

APPENDIX I (cont)

TABLE II

Opacity

CONTROL (Untreated)											AVG	STD
BASE:	85.4	84.2	84.7	84.4	83.4	84.0	84.3	82.9	84.6	84.1	84.2	0.654
COATED:	90.2	90.2	89.8	90.4	90.0	90.3	89.5	90.5	89.5	89.3	90.0	0.400
SUPERED:	88.4	88.5	88.5	88.4	89.8	88.4	88.9	89.1	88.3	89.2	88.8	0.463
1-A												
BASE:	84.0	84.8	84.7	84.7	84.3	83.7	84.4	85.5	84.1	84.9	84.5	0.493
COATED:	90.1	89.6	89.4	90.4	90.2	89.7	89.6	89.6	89.3	89.2	89.7	0.378
SUPERED:	89.4	88.8	89.2	88.3	89.2	89.3	88.6	88.6	88.8	88.1	88.8	0.417
1-B											AVG	STD
BASE:	84.1	84.7	84.1	84.1	84.4	85.4	84.5	84.2	84.7	84.6	84.5	0.384
COATED:	89.6	90.3	89.3	90.4	89.6	89.4	90.8	89.4	89.5	88.9	89.7	0.556
SUPERED:	88.3	88.8	87.4	88.4	87.4	88.2	88.7	88.2	88.7	88.3	88.2	0.467
1-C												
BASE:	84.8	83.9	84.1	84.4	83.4	84.2	83.7	84.3	84.5	84.3	84.2	0.385
COATED:	88.9	89.1	89.2	88.8	89.3	88.6	89.4	89.2	89.6	89.3	89.1	0.284
SUPERED:	88.1	87.7	87.5	88.0	88.3	89.1	88.7	88.8	88.2	88.4	88.3	0.469
2-A											AVG	STD
BASE:	84.1	84.1	81.7	84.3	85.0	84.0	83.4	84.9	84.4	85.2	84.1	0.951
COATED:	89.2	89.3	88.8	90.2	88.6	89.0	89.5	89.4	89.8	88.5	89.2	0.504
SUPERED:	88.3	87.5	89.0	88.4	89.4	88.0	89.2	89.4	88.8	88.3	88.6	0.602
2-B												
BASE:	85.9	86.3	86.2	85.4	84.8	85.1	85.0	85.3	85.4	85.3	85.5	0.478
COATED:	91.3	89.6	88.4	89.5	90.0	89.9	89.9	90.0	89.5	89.3	89.7	0.689
SUPERED:	89.2	88.8	88.5	88.5	88.7	87.5	88.8	88.9	89.0	89.4	88.7	0.490
2-C											AVG	STD
BASE:	84.6	85.6	84.0	84.8	83.5	83.8	85.0	83.5	84.1	84.1	84.3	0.650
COATED:	88.6	88.2	89.2	89.5	89.6	88.5	88.3	87.9	89.4	89.4	88.9	0.594
SUPERED:	87.4	87.2	87.4	87.0	87.9	88.3	87.7	87.0	88.4	87.8	87.6	0.472
3-A												
BASE:	83.4	84.1	84.7	84.3	84.2	84.3	85.5	84.7	84.4	83.5	84.3	0.572
COATED:	89.6	89.2	90.0	90.0	89.7	88.8	89.7	89.2	89.7	89.4	89.5	0.361
SUPERED:	87.5	88.5	87.7	88.2	88.0	87.1	88.1	90.3	88.3	87.8	88.2	0.815
3-B											AVG	STD
BASE:	84.3	83.9	84.4	84.1	83.5	84.4	84.6	84.9	84.8	83.7	84.3	0.436
COATED:	88.3	88.2	88.9	88.8	88.9	89.1	88.4	88.3	88.3	87.3	88.5	0.490
SUPERED:	87.8	87.5	87.4	87.4	88.2	87.9	87.8	87.3	86.5	87.5	87.5	0.434
3-C												
BASE:	83.3	83.5	83.8	83.2	84.4	83.7	83.1	83.5	83.8	84.2	83.7	0.398
COATED:	89.6	88.3	89.1	88.7	90.1	88.7	88.9	88.2	88.2	87.8	88.8	0.664
SUPERED:	88.4	87.4	87.0	86.9	88.0	87.2	87.4	88.2	87.3	87.7	87.6	0.482

APPENDIX I (cont)

TABLE III
Hunter Gloss

											AVG	STD
CONTROL (Untreated)												
BASE:	8.0	8.4	9.2	7.8	8.0	8.4	8.0	8.4	8.2	8.8	8.3	0.402
COATED:	28.3	27.8	28.4	28.0	28.2	28.9	27.5	28.1	28.6	28.4	28.2	0.379
SUPERED:	61.3	58.8	60.1	57.6	60.8	62.2	57.8	61.3	57.2	59.4	59.7	1.670
1-A												
BASE:	15.8	15.1	15.3	15.8	15.2	16.5	15.5	15.6	15.8	16.4	15.7	0.445
COATED:	31.8	33.0	30.7	31.6	31.3	31.1	30.9	30.8	31.9	31.4	31.5	0.647
SUPERED:	60.8	59.2	59.0	58.5	58.1	59.4	60.4	60.1	58.3	60.5	59.4	0.925
1-B											AVG	STD
BASE:	18.4	19.8	17.9	19.3	17.6	19.6	18.2	19.1	19.6	17.1	18.7	0.899
COATED:	31.4	32.3	33.0	32.2	31.5	32.3	30.3	33.5	31.8	32.9	32.1	0.876
SUPERED:	57.9	56.8	59.8	59.0	59.4	62.4	56.2	61.8	56.7	59.5	59.0	1.990
1-C												
BASE:	21.4	22.7	23.4	23.8	21.5	21.7	23.4	22.6	23.1	23.0	22.7	0.810
COATED:	34.9	34.1	34.2	34.5	34.8	34.6	34.2	35.0	34.7	35.2	34.6	0.352
SUPERED:	57.4	58.1	59.7	57.7	58.2	59.7	59.2	57.8	59.6	56.8	58.4	1.000
2-A											AVG	STD
BASE:	22.8	22.3	22.0	22.7	22.3	21.8	22.2	23.1	22.3	21.6	22.3	0.435
COATED:	32.8	33.6	32.4	33.5	33.0	33.0	32.9	33.0	32.5	34.4	33.1	0.558
SUPERED:	57.6	57.7	59.1	60.1	57.6	58.6	57.9	57.6	59.4	60.4	58.6	1.033
2-B												
BASE:	21.2	21.9	20.0	22.4	23.3	23.5	21.8	21.1	24.3	20.6	22.0	1.298
COATED:	37.1	34.6	37.0	35.7	36.7	36.1	37.1	36.6	35.5	36.3	36.3	0.771
SUPERED:	59.8	61.8	62.1	59.2	60.9	59.7	60.5	62.5	62.6	60.8	61.0	1.155
2-C											AVG	STD
BASE:	26.0	25.8	26.5	24.3	25.4	25.9	25.3	26.8	26.3	25.1	25.7	0.700
COATED:	38.3	38.9	39.0	39.7	40.1	40.4	40.8	40.8	40.2	40.1	39.8	0.800
SUPERED:	62.5	63.9	62.9	61.9	61.8	63.5	64.1	63.6	63.4	61.8	62.9	0.843
3-A												
BASE:	21.7	21.9	21.7	21.3	21.5	24.1	22.1	24.3	22.1	24.0	22.5	1.115
COATED:	35.6	34.4	34.9	37.0	35.4	36.6	36.3	36.1	35.9	36.2	35.8	0.745
SUPERED:	60.2	60.8	63.8	60.8	60.0	61.7	61.8	62.5	62.2	62.6	61.6	1.133
3-B											AVG	STD
BASE:	26.8	27.1	27.9	26.4	26.3	27.1	25.6	27.0	28.2	26.8	26.9	0.714
COATED:	41.7	41.3	42.0	41.5	41.7	41.9	41.2	42.0	38.5	41.5	41.3	0.979
SUPERED:	62.2	62.5	62.0	61.2	59.7	62.2	61.7	61.9	62.6	62.3	61.8	0.808
3-C												
BASE:	29.7	31.0	29.4	31.0	29.3	32.4	30.2	29.2	32.0	30.6	30.5	1.069
COATED:	41.0	42.3	40.9	43.1	42.1	41.5	42.1	41.9	41.9	40.7	41.8	0.697
SUPERED:	65.0	63.1	66.0	62.8	64.6	64.1	63.8	65.6	65.1	64.3	64.4	0.979

APPENDIX I (cont)
TABLE IV
Parker Print Roughness (10 kgf)

CONTROL (Untreated)											AVG	STD
BASE:	4.45	4.85	4.60	4.55	4.45	4.50	5.05	4.40	4.85	4.55	4.63	0.205
COATED:	3.15	3.30	3.15	3.25	3.35	3.35	3.20	3.40	3.45	3.30	3.29	0.097
SUPERED:	1.20	1.30	1.20	1.20	1.20	1.20	1.25	1.35	1.25	1.25	1.24	0.049
1-A												
BASE:	3.50	3.30	3.25	3.25	3.55	3.60	3.40	3.55	3.35	3.45	3.42	0.123
COATED:	2.45	2.65	2.65	2.45	2.45	2.25	2.55	2.40	2.50	2.45	2.48	0.112
SUPERED:	1.10	1.25	1.20	1.25	1.30	1.15	1.15	1.35	1.50	1.25	1.25	0.110
1-B											AVG	STD
BASE:	3.05	3.15	3.20	3.15	3.20	3.05	3.25	2.95	3.30	3.20	3.15	0.100
COATED:	1.85	1.75	1.90	1.85	1.80	1.80	1.75	1.80	1.70	1.95	1.82	0.071
SUPERED:	1.25	1.20	1.20	1.10	1.15	1.25	1.25	1.25	1.15	1.30	1.21	0.058
1-C												
BASE:	2.70	2.75	2.70	2.80	2.85	2.85	2.75	2.75	2.65	2.70	2.75	0.063
COATED:	1.75	1.70	1.80	1.80	1.70	1.75	1.70	1.75	1.70	1.70	1.74	0.039
SUPERED:	1.30	1.20	1.10	1.30	1.25	1.25	1.20	1.15	1.30	1.30	1.24	0.067
2-A											AVG	STD
BASE:	3.05	3.15	3.15	3.00	2.90	3.00	2.95	3.15	2.95	3.10	3.04	0.089
COATED:	2.35	2.30	2.00	2.15	2.25	2.20	2.00	2.15	2.30	1.90	2.16	0.143
SUPERED:	1.55	1.40	1.45	1.30	1.40	1.30	1.30	1.45	1.25	1.50	1.39	0.094
2-B												
BASE:	3.25	3.35	3.35	3.15	3.40	3.70	3.20	3.70	3.35	3.50	3.40	0.180
COATED:	1.95	1.95	2.20	2.60	2.50	2.35	2.55	2.30	2.35	2.30	2.31	0.213
SUPERED:	1.50	1.40	1.50	1.45	1.30	1.45	1.50	1.50	1.45	1.50	1.46	0.061
2-C											AVG	STD
BASE:	3.15	3.00	3.20	3.05	3.00	3.05	2.80	3.20	2.95	2.10	2.95	0.306
COATED:	1.70	1.85	2.10	1.85	1.85	1.90	1.90	2.25	2.10	2.25	1.98	0.178
SUPERED:	1.65	1.60	1.60	1.65	1.65	1.65	1.60	1.60	1.40	1.40	1.58	0.093
3-A												
BASE:	3.45	3.75	3.60	3.80	3.45	3.80	3.70	3.65	3.60	3.60	3.64	0.120
COATED:	2.70	2.75	2.65	2.70	2.90	2.80	2.90	2.80	2.70	2.60	2.75	0.095
SUPERED:	1.40	1.50	1.35	1.40	1.50	1.40	1.40	1.50	1.50	1.35	1.43	0.060
3-B											AVG	STD
BASE:	3.10	3.25	3.30	3.25	3.25	3.40	3.30	3.45	3.40	3.30	3.30	0.095
COATED:	1.75	1.70	1.95	2.05	1.90	1.70	1.90	1.90	2.15	1.64	1.86	0.156
SUPERED:	1.45	1.40	1.45	1.40	1.50	1.50	1.50	1.55	1.40	1.50	1.47	0.050
3-C												
BASE:	2.70	3.00	2.95	2.85	3.15	2.90	3.00	3.15	2.90	3.10	2.97	0.135
COATED:	1.95	1.85	1.65	1.60	2.10	1.90	2.00	1.95	1.95	1.90	1.89	0.145
SUPERED:	1.35	1.40	1.35	1.40	1.40	1.45	1.30	1.40	1.40	1.25	1.37	0.056

APPENDIX II

Coat Weight and Legend

Base(500g)	10.323 g/m^2		
1-A (500g)	7.162 g/m^2		
1-B (1000g)	7.637 g/m^2		
1-C (500g)	6.943 g/m^2		
		Average:	7.083 g/m^2
2-A (500g)	7.107 g/m^2	STD:	0.280
2-B (500g)	6.687 g/m^2	MAX:	7.637 g/m^2
2-C (500g)	6.705 g/m^2	MIN:	6.687 g/m^2
3-A (200g)	7.308 g/m^2		
3-B (500g)	6.997 g/m^2		
3-C (200g)	7.198 g/m^2		

LEGEND

Temperatures:

1= 284°F
2= 374°F
3= 464°F

Pressures:

A= 750 pli
B= 1250 pli
C= 1750 pli