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Supercalender Variables for Release Liner

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SUPERCALENDER VARIABLES FOR RELEASE LINER

By

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ABSTRACT

This senior engineering design project studies the effect of increased steel roll temperature and increased sheet moisture on the supercalendering of uncoated release backing paper. Sheets were supercalendered using a Beloit Wheeler laboratory supercalender fitted with a temperature controller. The moisture of the sheets was adjusted using 20 and 80% R.H. humidity chambers.

An increase in gloss, densometer and reduction in caliper were evident with the increase of both the steel roll temperature and sheet moisture. Increased sheet moisture seemed to have little effect on the Sheffield Smoothness values. However, the increase in steel roll temperature did product improved smoothness.

Keywords: supercalendering, release backing, temperature, moisture.

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INTRODUCTION

The purpose of this senior engineering design project is to investigate supercalender variables to improve the gloss and smoothness of release backing papers.

Release papers are required to meet stringent and specific requirements. Solventless silicone coating systems especially place high chemical and physical demands on the sheet. The furnish for release grades usually consists of highly refined hardwood and softwood kraft pulps. High smoothness, gloss, surface density, and low caliper variations are a few of the most important sheet properties demanded by the silicone coating and die cutting operations involved with release backing.

There are four main variables for the supercalendering of paper speed, pressure, roll temperature, and sheet moisture. Since temperature and moisture content are the two main factors effecting the plasticity of cellulose, this study will only address the steel roll temperature and sheet moisture variables (3, 4, 5, 6). The supercalender speed, and pressure will be held constant.

THEORETICAL DISCUSSION

Supercalendering Theory

The supercalender is a piece of equipment consisting of alternating hard metal and soft rolls. The rolls are loaded to extreme pressures which cause the soft rolls to deform. This deformation causes relative motion of the soft roll against the hard roll, producing rolling friction which gives the polishing and smoothing effects of the supercalendering process.

The majority of the changes which occur in the supercalender depend upon the elastic properties of the fibers themselves. The most important effect upon the fibers is the replication of the surface against which they are pressed (1). Since the steel or iron rolls in the supercalender can be ground smoother that the soft rolls, the largest gloss development occurs against the steel roll (1). For the replication of the roll surface to occur, the glass transition temperature of the sheet surface must be reached.

Glass Transition Point

The effect of using a high temperature on the steel roll is to set up a temperature gradient (1). As a result, the properties through the sheet will be variable. The result of the gradient is a final sheet with better smoothness at the same or higher bulk.

The level of moisture in the sheet effects both the elastic modulus and the glass transition temperature, and therefore control of the moisture is extremely important (1). The glass transition temperature of cellulose is the region where it changes from a rigid glassy material to a soft plastic material (2). Water acts as a plasticizer for the amorphous regions of the cellulose in the fiber walls (2). As a result adding a few percent moisture to the sheet greatly reduces the glass transition temperature of the fibers. Lignin and hemicellulose tend to broaden the temperature range at which the fibers soften (2).

Hypothesis

It is expected from the previous work completed concerning the supercalendering of both coated and uncoated grades that the increase in sheet moisture should reduce the glass transition temperature. This reduction in the glass transition temperature will allow the fibers to more easily mold to the smooth roll surface producing higher gloss and smoothness values. The increase in temperature will allow for more of the fibers in the sheet to reach their transition point thus increasing the gloss and smoothness of the sheet. Both the increase in temperature and moisture should increase the Gurley Densometer values.

EXPERIMENTAL PROCEDURE

Background

Trial work was completed on this senior engineering design project at Simpson Plainwell Paper Company, Plainwell, Michigan under the supervision of Philip Anglin. A Beloit Wheeler laboratory supercalender fitted with an electronic temperature contoller was used.

Procedure

This two factor, three level experiment was designed to demonstrate the effects of temperature and moisture content on the supercalendering of release backing papers. A total of nine different conditions were studied. Twelve repetitions were completed on each of the conditions. To be statistically correct the order of the calendering of the samples and conditions should be completely randomized. In this case, there are one-hundred and eight samples to evaluate. Approximately thirty minutes must be allowed for the supercalender temperature to reach equilibrium after each change. As a result, given the number of samples to be run randomization of the conditions would be extremely time consuming. In the interest of time the samples were run in blocks of twelve.

Samples of uncalendered release stock will be passed through a laboratory supercalender using three moisture and steel roll temperature levels. The caliper, smoothness and densometer readings will be taken before and after supercalendering.

Humidity chambers will be used to adjust the sheet moisture. The control sheets will be conditioned at TAPPI standard conditions of 50% relative humidity (7). The high moisture samples will be placed in a 80% relative humidity chamber. The low moisture samples will be placed in a 20% relative humidity chamber.

The steel roll temperature will be controlled by an electronic temperature control on the laboratory stack. The target temperatures will be 150, 175, and 200 degrees Fahrenheit. These temperatures were chosen to give a broad range of temperature. This range will also give data for temperatures above and below the standard temperature run during production runs of release backing.

The properties that will be monitored are caliper and caliper reduction, surface density (densometer, 8), gloss (9) and smoothness (10). In addition the sheet moisture (11), actual steel roll temperature, filled roll temperature will be recorded.

RESULTS PRESENTATION

Table 1 -- Gloss Results

Trial	Sheet Moisture	Steel Roll Temperature	Hunter Gloss
G	4.5%	150oF	31.6
H	4.5%	175oF	34.2
I	4.5%	200oF	35.4
A	6.5%	150oF	32.7
B	6.5%	175oF	35.0
C	6.5%	200oF	39.3
D	8.5%	150oF	43.3
E	8.5%	175oF	46.2
I	8.5%	200oF	46.9

Table 2 -- Densometer Results

Trial	Sheet Moisture	Steel Roll Temperature	Gurly Densometer (Seconds)		
			Initial	Final	Difference
G	4.5%	150oF	1835	3165	1330
H	4.5%	175oF	1954	3425	1471
I	4.5%	200oF	2287	3283	995
A	6.5%	150oF	1763	4701	2939
B	6.5%	175oF	1760	5279	3519
C	6.5%	200oF	1851	8714	6863
D	8.5%	150oF	1759	12175	10416
E	8.5%	175oF	1723	20070	18348
I	8.5%	200oF	2072	29108	27036

Table 3 -- Caliper Results

Trial	Sheet Moisture	Steel Roll Temperature	Caliper (0.001") Initial	Final	Difference
G	4.5%	150oF	4.33	2.91	1.41
H	4.5%	175oF	4.37	2.86	1.50
I	4.5%	200oF	4.40	2.81	1.59
A	6.5%	150oF	4.25	2.90	1.34
B	6.5%	175oF	4.35	2.91	1.43
C	6.5%	200oF	4.27	2.84	1.43
D	8.5%	150oF	4.36	2.77	1.59
E	8.5%	175oF	4.25	2.76	2.75
I	8.5%	200oF	4.29	2.75	1.54

Table 4 -- Sheffield Smoothness

Trial	Sheet Moisture	Steel Roll Temperature	Sheffield Smoothness Initial	Final	Difference
G	4.5%	150oF	305.4	79.8	225.7
H	4.5%	175oF	304.2	81.3	222.8
I	4.5%	200oF	324.6	80.7	243.9
A	6.5%	150oF	290.0	86.3	203.7
B	6.5%	175oF	304.2	74.6	229.6
C	6.5%	200oF	298.8	73.9	224.8
D	8.5%	150oF	320.4	84.9	235.5
E	8.5%	175oF	290.4	74.3	216.2
I	8.5%	200oF	287.9	75.6	212.3

Figure 1
EFFECT OF TEMPERATURE ON GLOSS
AT VARIOUS MOISTURE LEVELS

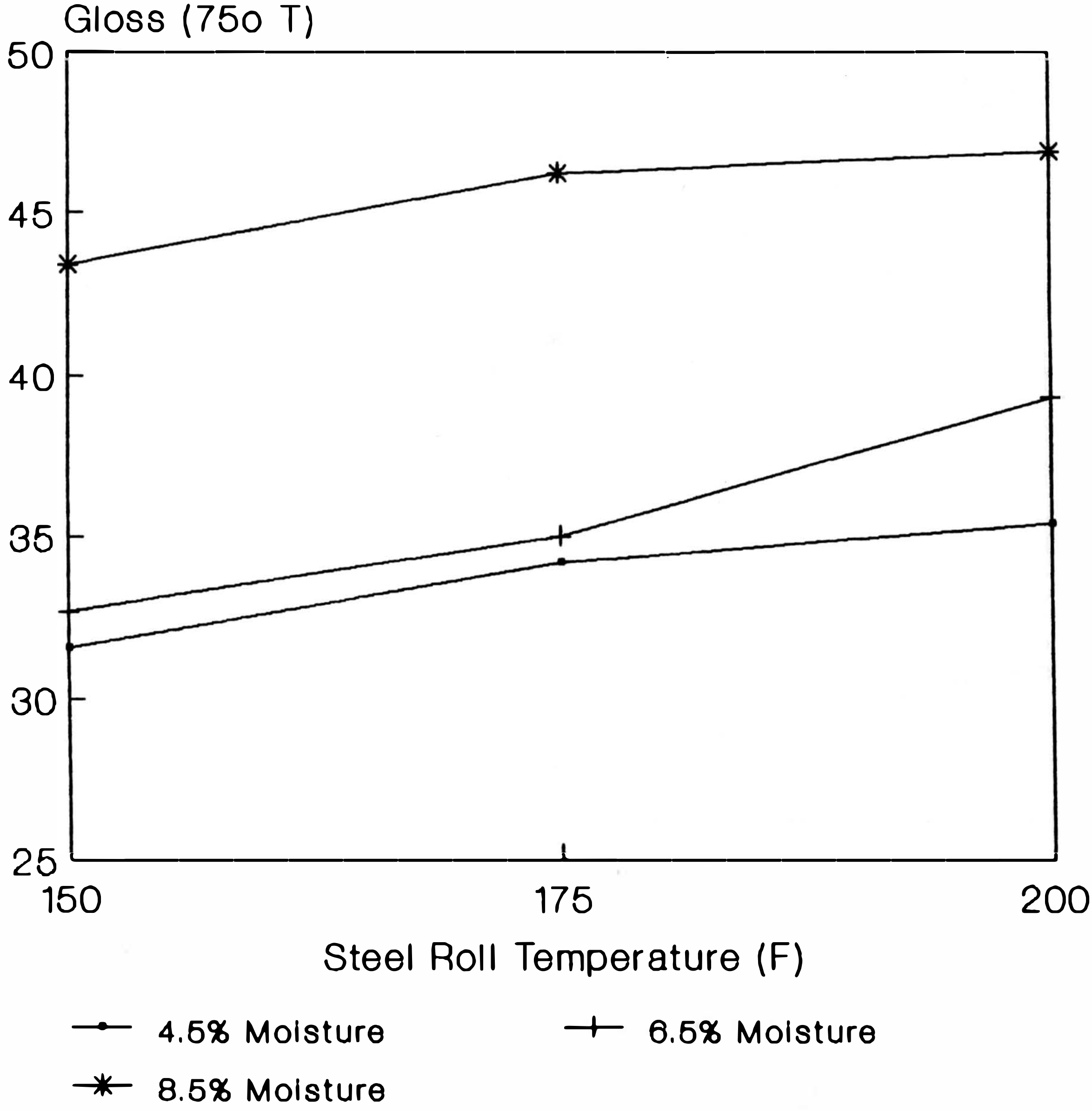


Figure 2
EFFECT OF TEMPERATURE ON DENSOMETER AT VARIOUS MOISTURE LEVELS

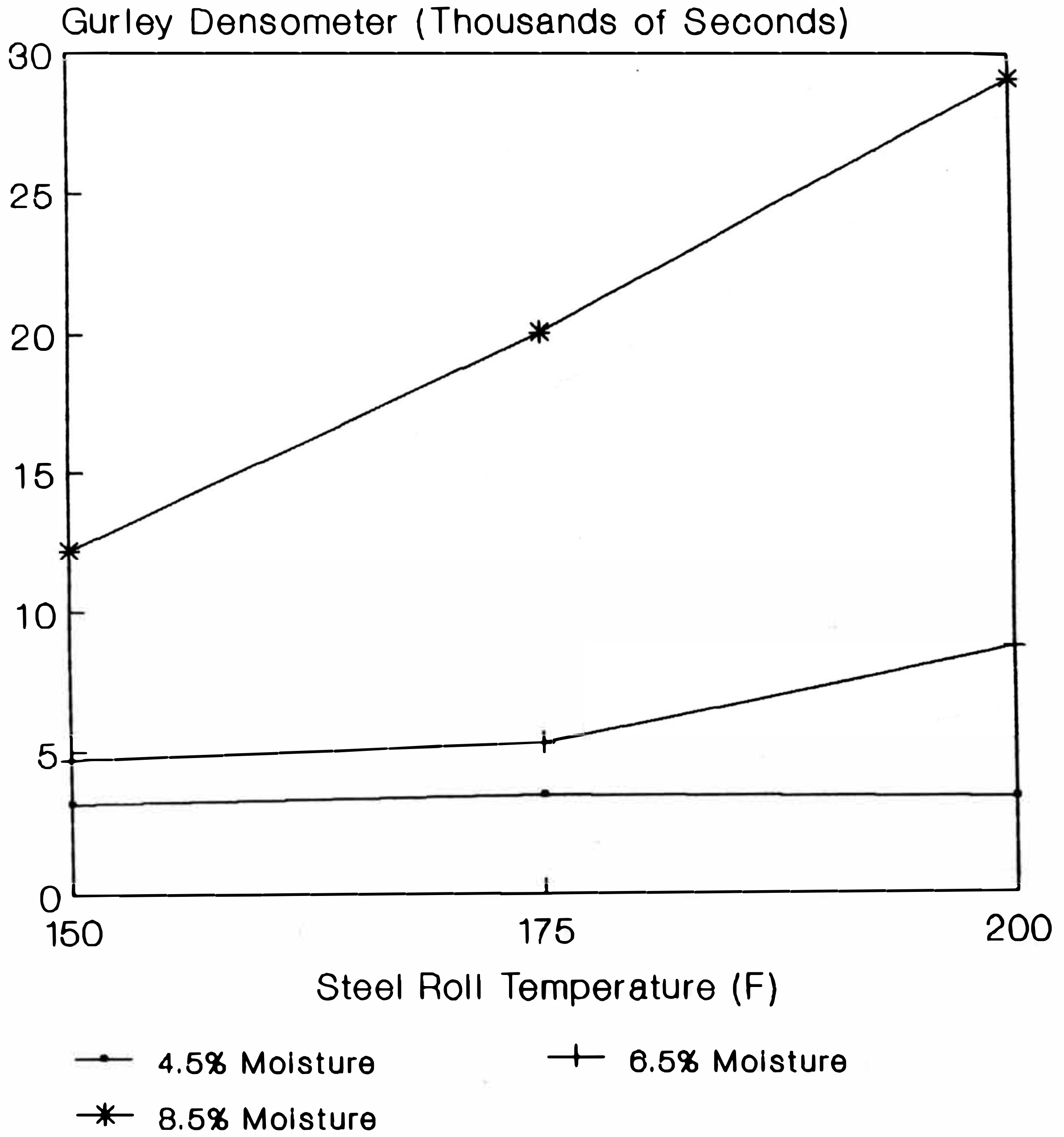


Figure 3
EFFECT OF TEMPERATURE ON DENSOMETER INCREASE AT VARIOUS MOISTURE LEVELS

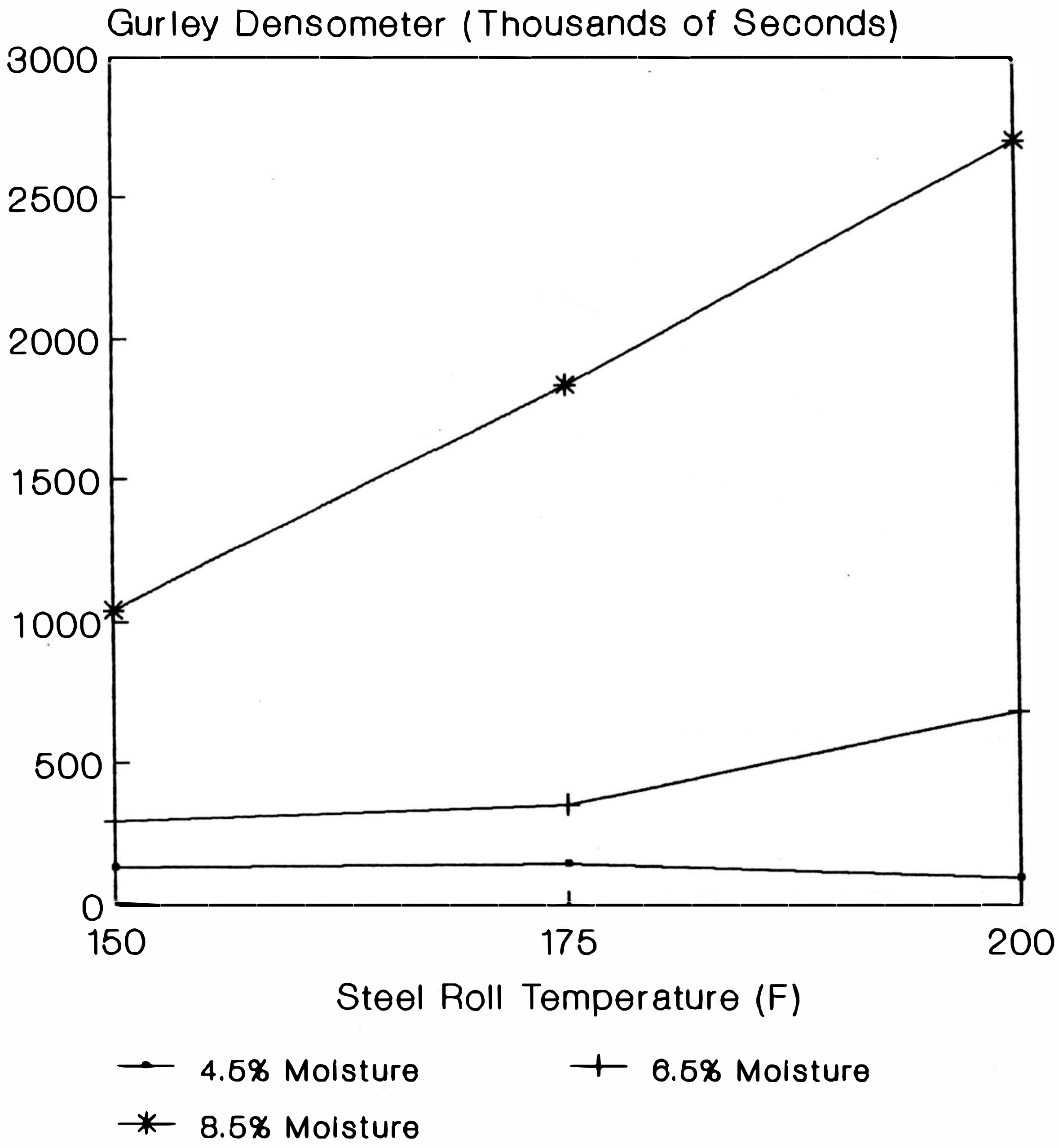


Figure 4
EFFECT OF TEMPERATURE ON CALIPER AT VARIOUS MOISTURE LEVELS

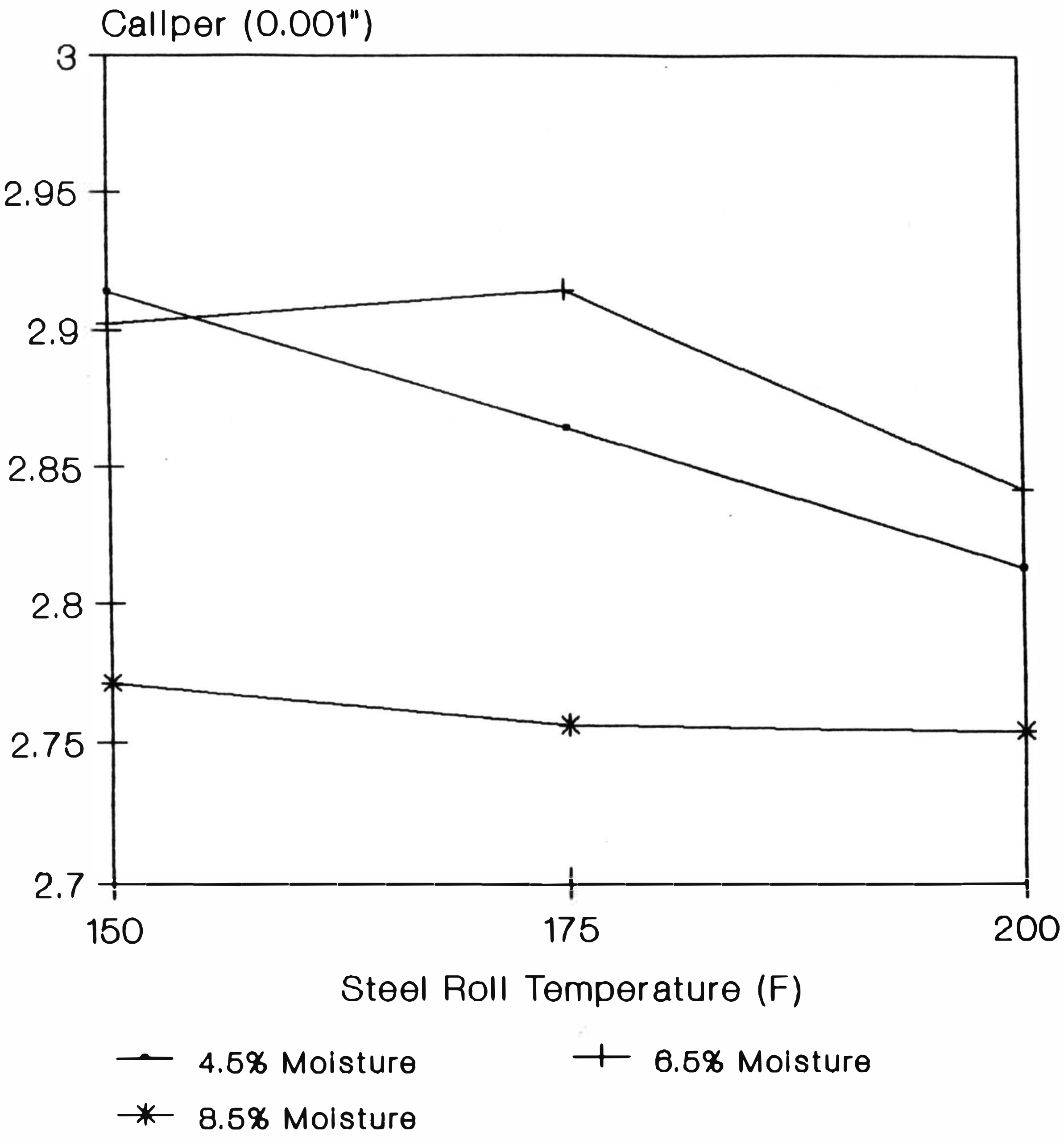


Figure 5
EFFECT OF TEMPERATURE ON CALIPER REDUCTION AT VARIOUS MOISTURE LEVELS

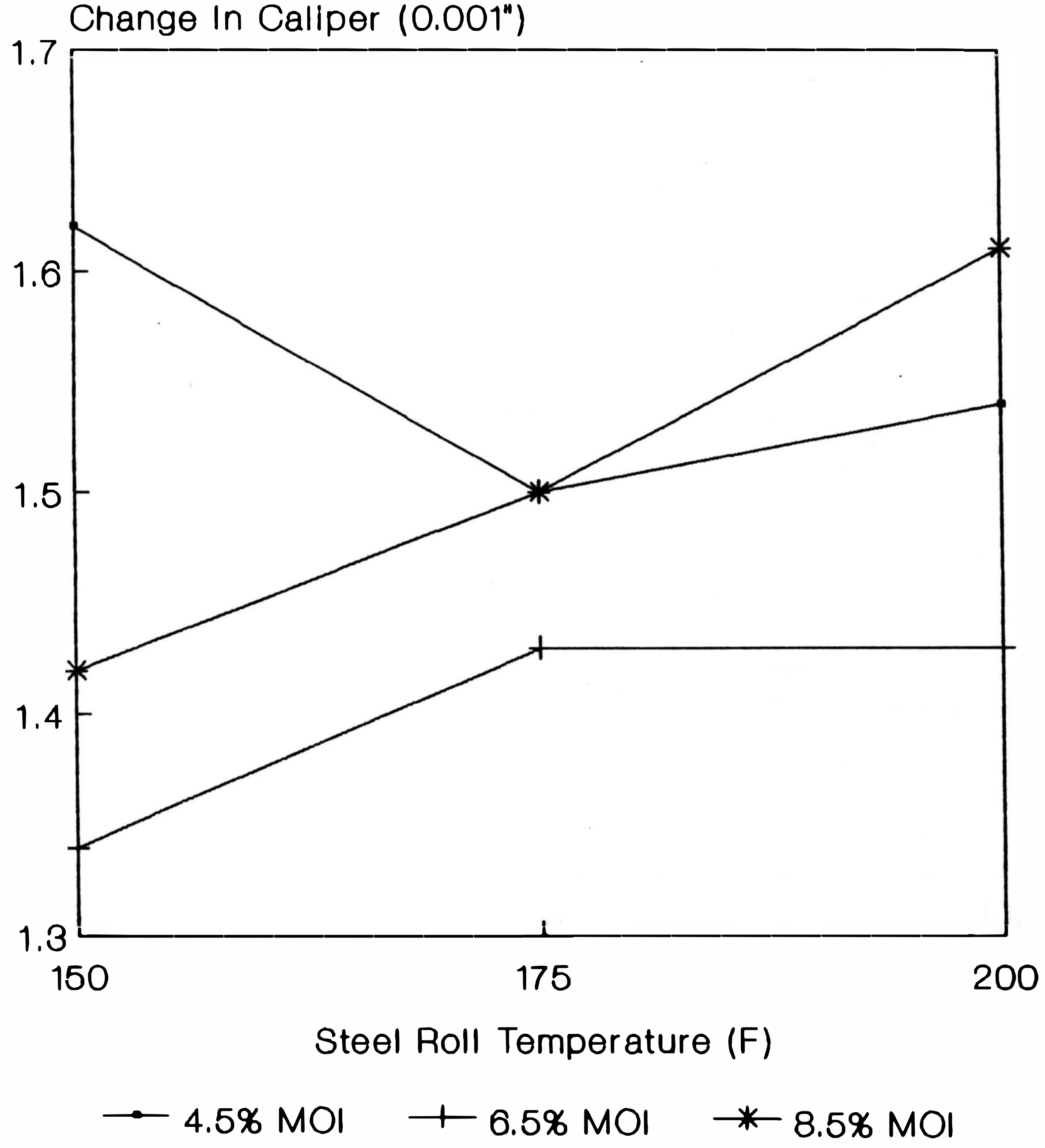


Figure 6
EFFECT OF TEMPERATURE ON SMOOTHNESS AT VARIOUS MOISTURE LEVELS

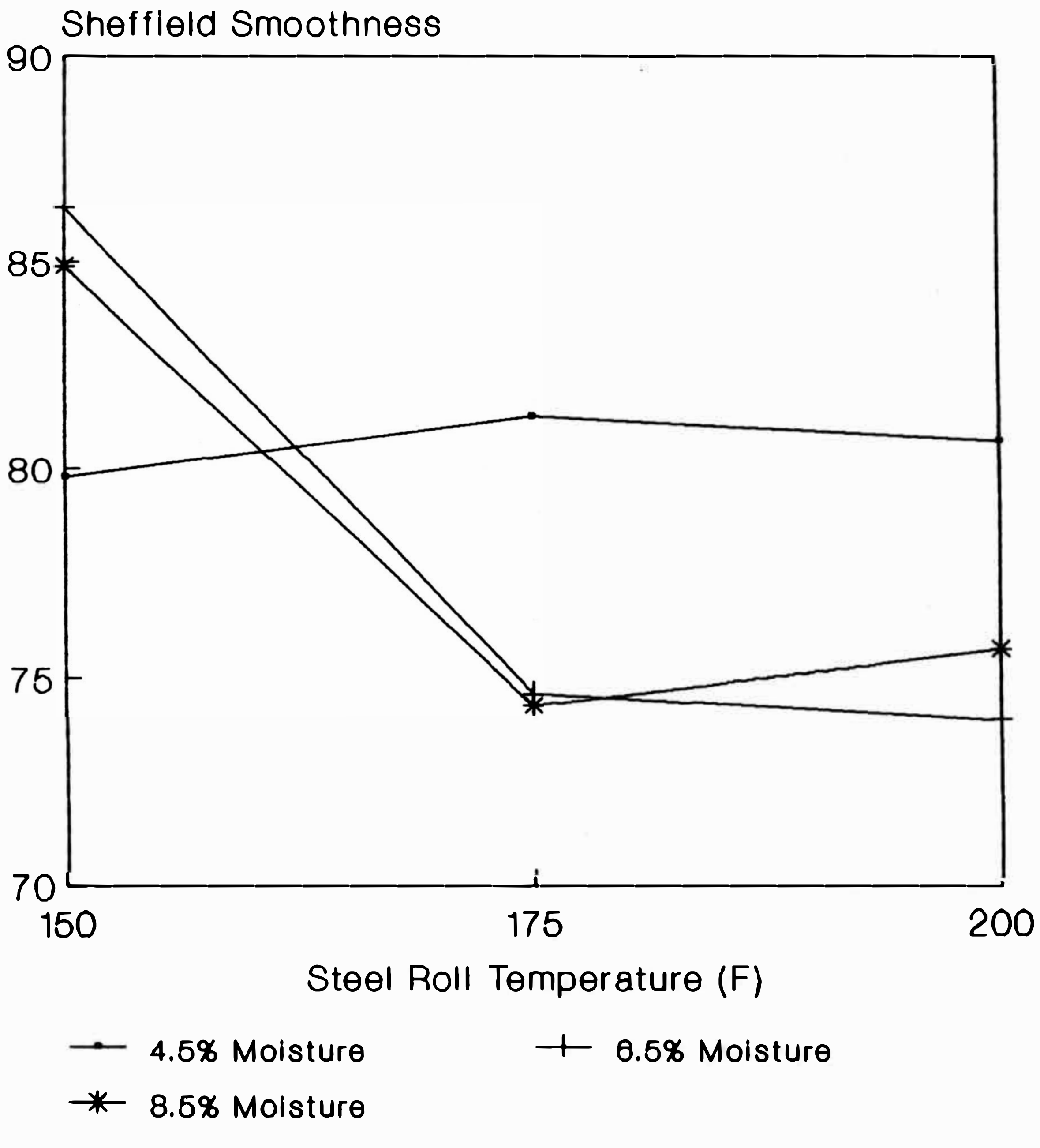
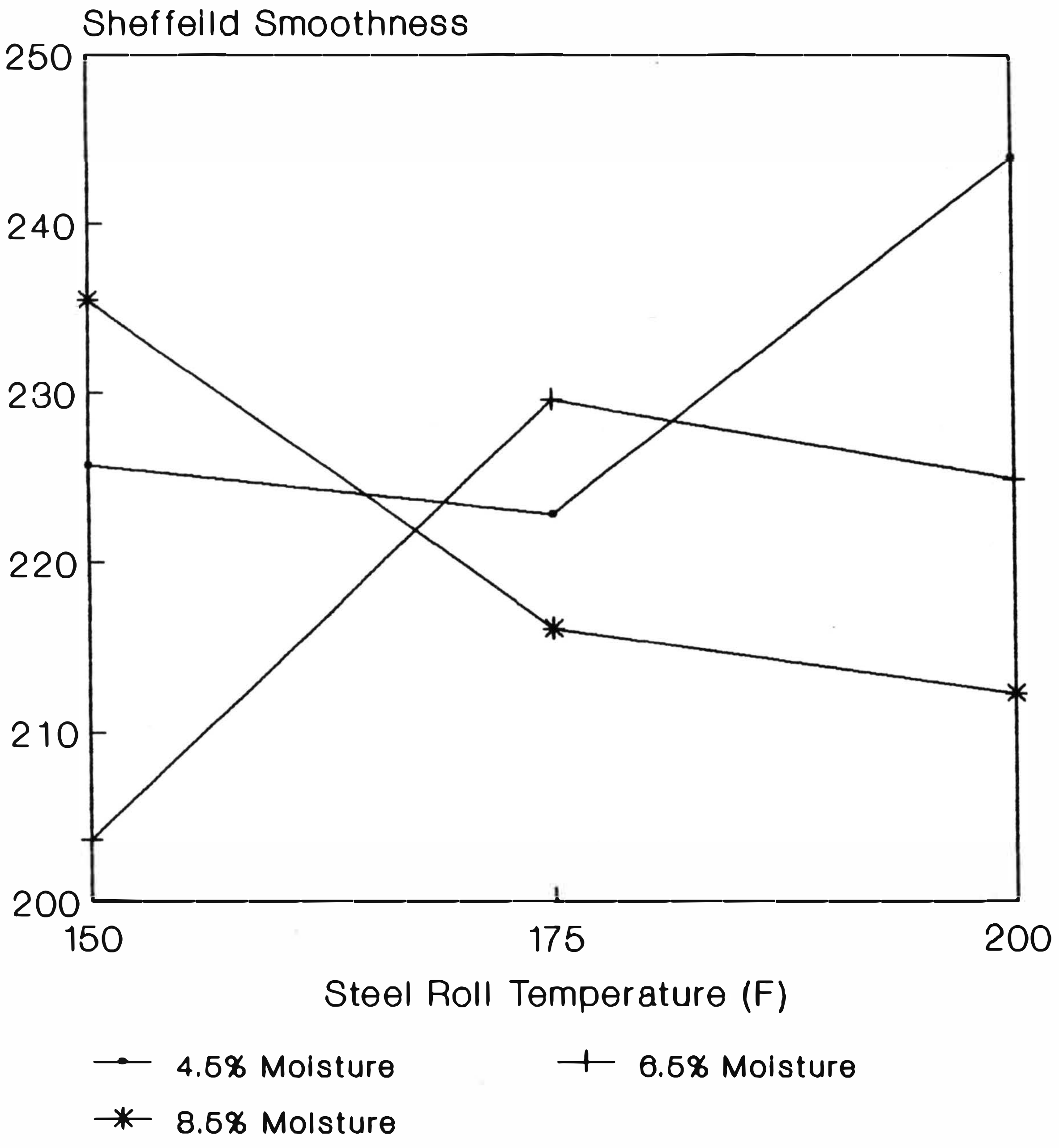


Figure 7
EFFECT OF TEMPERATURE ON SMOOTHNESS IMPROVEMENT AT VARIOUS MOISTURE LEVELS



DISCUSSION OF RESULTS

Statistical Analysis

A statistical analysis of the fixed variables was completed. The analysis is designed to test the resulting data to find if there is any significant change in the mean value of each condition as compared to the overall mean of the population. ANOVA tables were generated for the following values: Gloss, Guerly Densometer, smoothness and caliper reduction. The significance is tested by using a "F" test. This test involves comparing the ratio of the mean square of the treatment or interaction to the mean square of the error. If this values is greater than the "F" statistic value from the standard tables, the evidence is significant enough to reject the null hypothesis which states that the mean value for each factor and level are equal. If the variation due to the interaction is significant, it is said that the factors are interrelated. This interaction makes the analysis of the results more difficult to evaluate. To assist in the analysis, graphs of the mean response at each treatment combination were evaluated. These graphs are located in the results section of this report.

Gloss

The results of the gloss values can be seen in table 1 in the results section. The mean values of the gloss increase with both temperature and pressure. The analysis of variance performed on the data proves that the variance is significant for both the temperature and moisture factors.

The calculated "F" value for the moisture factor is considerably larger than the Fo as can be seen in table 5 in appendix A suggesting that the moisture has a large effect on the gloss development. From looking at figure 1, it is evident that there are only moderate differences between the low and medium moisture levels and quite a large difference due to the high moisture level. These results are as expected from the work of Roundsley (1) and Back (3). From their work it is believed that moisture in the sheet tends to act as a plasticiser reducing the glass transition point of the amorphous regions of the cellulose chains.

The ANOVA of temperature conditions has proven that there are significant differences due to the changes in the temperature of the steel roll in the supercalender. Only moderate differences where noticed in figure 1 in the results section. The increase in temperature seemed to increase the gloss in all cases as was expected from the literature. The largest increase due to temperature was seen at the 6.5% moisture level. The glass transition temperature of paper is a temperature band. Since paper is heterogeneous all of the fibers due not reach their glass transition point at the same temperature. With the higher temperature of the steel roll the sheet is raised to a higher temperature allowing more of the fibers to reach their Tg increasing the amount of plasticised fibers and thus the gloss. From figure 1 it is also evident that the larger moisture levels produce larger supercalendered gloss values.

Densometer

Similar results where found in the Gurley Densometer values. The moisture and temperature ANOVA results in table 6 of appendix A suggest that the variance due to both the temperature and moisture levels is significant. Again the moisture factor demonstrated the greatest increase in the Densometer values. The samples with high moisture acquired the largest values at all three temperature levels as can be seen in figure 2 in the results section. The medium and low moisture levels resulted in similar values. The medium moisture level was effected the most at the high temperature level with slight to no increase between the low and medium temperature. The mean values for the low moisture samples demonstrated very little change from the low to the high temperature. These lower levels of change at the 4.5% and 6.5% moisture levels tends to suggest that there may be a moisture threshold that must be reached to achieve larger increases in the flow or molding of the fibers in the supercalender.

For proper solvent holdout to be achieved in the silicone release coating of the sheet large Gurley Densometer values are crucial. As a result moisture levels of the 7 to 8.5 percent range are necessary.

Caliper

The results of the caliper testing can be found in table 3 and table 4 of appendix A with the ANOVA results in table 7 and table 8. The variance due to both the temperature and moisture were proven to be significant for both the caliper and caliper reduction.

From figure 3 it is evident that the change in moisture affected the caliper more so than the change in steel roll temperature. This is supported by the ANOVA results in table 7. After inspecting figure 3, it is seen that the increase in moisture in the sheets caused considerable loss in caliper most noticabley at the higest moisture level (8.5% level). At this moisture level the temperature had little effect.The low and medium moisture level lines in figure 3 revealed nearly the same values at the three temperature levels.

The effect due to the different temperature levels was not as significant (see table 7). The caliper drop due to the rise in temperature from 150oF to 200oF produced only a 0.007" drop at the low and medium moisture levels. The caliper drop at the high moisture level was very small only 0.002".

The caliper reduction data was caluculated by subtracting the inital caliper readings from the supercalendered values. The average values can be found in table 4 in the result section. It is can be seen that the values are significant due to both temperature and moisture; however, the interaction is also significant (see table 8). From figure 4 it is seen that the 6.5% and 8.5% moisture lines seem to trend is the same shape with the 8.5% line giving larger values at every temperature level. The 4.5%

moisture line did not trend as the other lines, which was surprising because the caliper data seemed to trend the same as the others at that moisture level.

Smoothness

The Sheffield smoothness data can be found in table 5, Table 9 and figure 5. The variance do to the different moisture levels was statisically proven to be insignicant at the 99% confidence level. However, the variance do to the changes in the steel roll temperature was proven to be significant. The interaction between the temperature and moisture was proven significant. From figure 5 it is seen that the smoothness values at the 6.5% and 8.5% levels follow the same trend of droping with increased steel roll temperature. The 4.5% moisture level remained nearly constant over the entire temperature range. These results tend to suggest that there is a break point at which the necessary temperature and moisture level must be met to improve the smoothness.

CONCLUSIONS

1. The increase in both steel roll temperature and sheet moisture improved the supercalendered gloss values with the sheet moisture having a larger effect than the steel roll temperature.
2. The Gurley Densometer results increased with both steel roll temperature and sheet moisture levels. Again with the sheet moisture having a larger effect than the change in steel roll temperature.
3. A loss in caliper was evident with increasing steel roll temperature and sheet moisture with the sheet moisture having a larger effect than the steel roll temperature.
4. An increase in smoothness was seen with the increase in steel roll temperature; however, the sheet moisture levels seemed to have little effect on the smoothness.

RECOMMENDATIONS

1. Further study of the effects of increased steel roll temperature and sheet moisture on the smoothness of unsupercalendered sheets.
2. Some improvements could be made in the statistical analysis by completely randomizing the order in which the calendering conditions are run.
3. An industrial sized trial run with sheet moistures adjusted at the paper machine would also be useful.

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APPENDIX

Table 5 -- Analysis-of-Variance: Gloss

Source	SS	df	MS	F	F(0.01,r1,r2)
Moisture	2858.4	2	1429.20	470.55	4.75
Temperature	391.6	2	195.80	64.47	4.75
Interaction	54.31	4	13.58	4.47	3.42
Error	300.69	99	3.04		
Total	3605	107			

Table 6 -- Analysis-of-Variance: Densometer

Source	SS	df	MS	F	F(0.01,r1,r2)
Moisture	58441009	2	29220504	86.72	4.75
Temperature	9208831	2	4604415.	13.66	4.75
Interaction	9167184	4	2291796	6.80	3.42
Error	33358309	99	336952.6		
Total	1.1E+08	107			

Table 7 -- Analysis-of-Variance: Caliper

Source	SS	df	MS	F	F(0.01,r1,r2)
Moisture	0.98	2	0.49	55.11	4.61
Temperature	0.21	2	0.11	11.81	4.61
Interaction	1.29	4	0.32	36.27	3.32
Error	2.801	315	0.01		
Total	5.281	323			

Table 8 -- Analysis-of-Variance: Caliper Reduction

Source	SS	df	MS	Fo	F(0.01,r1,r2)
Moisture	1.15	2	0.58	57.14	4.61
Temperature	0.27	2	0.14	13.41	4.61
Interaction	2.09	4	0.52	51.92	3.32
Error	3.17	315	0.01		
Total	6.68	323			

Table 9 -- Analysis-of-Variance: Sheffield Smoothness

Source	SS	df	MS	F	F(0.01,r1,r2)
Moisture	129.13	2	64.57	1.28	4.75
Temperature	1157.4	2	578.70	11.46	4.75
Interaction	2125.7	4	531.43	10.52	3.42
Error	4999.6	99	50.50		
Total	8411.83	107			