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Effect of Hot Supercalendering On Sheets with High Filler Loadings and Polypropylene Fibers Added

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EFFECT OF HOT SUPERCALENDERING ON SHEETS WITH HIGH FILLER LOADINGS AND POLYPROPYLENE FIBERS ADDED

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ABSTRACT

This study investigates the effects of hot supercalendering on sheets with high filler loadings and polypropylene pulp added. An uncoated sheet that had sheet and optical characteristics similar to a coated number three sheet was desired. Research was conducted in two stages, handsheet analysis and a machine trial on Western Michigan University's Fourdrinier Pilot Plant. The hot supercalendering of these sheets with 15% Pulpex resulted in a 111% increase in Scott Bond. Unconsolidated Pulpex has no synergestic effects with clay fillers for gloss, brightness, and opacity. Pulpex that has been consolidated does have a synergistic effect with clay for gloss.

Keywords: Polypropylene Pulp, Hot Supercalendering, High Filler Loading.

TABLE OF CONTENTS

Mailing costs for magazines are directly associated with basis weight. As postage costs increase to over eight cents per magazine in 1979 from only 1.8 cents in 1970, publishers are demanding lighter weight papers and production trends indicate this. Fifteen years ago, 40 lb. paper was considered light weight paper for high volume magazines. In the late 1960's a shift to 36 lb. paper was made. Today, the major grade is 34 lb. with 32 lb. and even 30 lb. sheets available.(1)

The objective of this thesis was to determine how hot supercalendering effects the internal strength, surface characteristics and optical properties of sheets containing high levels of filler clay and low levels of polypropylene fibers. This study evaluated how these combinations could be used as a substitute for lower grade, lighter weight magazine stock.

Printers are interested in the available area of the sheet purchased, and since paper is sold on a weight basis, they pay a premium for light weight grades. Also, as the basis weight decreases, the paper losses from poor runnability increase dramatically. Consideration of these problems, from a publishers view, must be balanced against the reduced distribution costs, which can be substantial for large circulation magazines.(1)

One important factor for the light weight grades for determining the amount of coating color necessary is surface smoothness. Other factors are considered depending upon the method of printing. Offset printing, which represents the major tonnages, requires both a fairly smooth sheet and good pick resistance because of the tacky inks used. Gravure printing, which is used for very long runs, requires a smooth sheet that has controlled ink receptivity. Finally, letterpress printing, which is still extensively used, is the least demanding for surface characteristics. However, if the basis weight becomes too low, the strike through represents a problem.(2)

Paper mills report that there is neither a marginal increase or decrease in profitability when producing the light weight grades. Technological efforts have been concentrated in maintaining press runability and surface characteristics while reducing the basis weight. Publishers have been willing to give up some opacity if runnability and printing characteristics, such as ink hold out and ink gloss, are preserved.(1,2)

Mills have been using bleached kraft fibers to maintain the strength and runability characteristics such as tearing strength of the paper. There has been much discussion about the quantity of these fibers to add, and machine and press runability must be maintained, as these are the predominate factors.(1,8) Another approach has been in the addition of wet end chemicals such as starches, gums, and synthetic polymers for strength increases. When the desired strength levels are obtained from kraft fibers, groundwood fibers are usually added to increase the sheet opacity and smoothness. This trend is reported increasing, especially as TMP capacity increases.(1)

Effect of Increased Filler Content

It has been well established that by increasing the mineral filler content of a paper web, it will have a pronounced weakening effect. Past experience has found that the effective surface area of the filler has a significant importance to these strength losses.(4) Two approaches can be used to reduce the effective surface area. The first is to use larger clay particles and the second is to use small clay particles that have been flocculated into larger units. This latter method has proven to have better results.(4) A higher aggregated filler would have a lower effective surface area to disrupt the fiber-fiber bonding. This can be easily seen by graphing the stength value, such as burst or tensile, directly against the surface

area of the added filler.(4) A disadvantage from the aggregated filler is that the opacity is reduced. This is expected because the larger flocculated particles will perform worse in scattering light compared to the smaller unflocculated particles.

The effects of using reduced fines in a filler clay can be summarized as follows:(3,4)

1. A coarse filler will be less opacifying, but the increased loading level could compensate

2. A coarse filler will increase ink vehical strike through, but higher loadings could compensate

3. A coarse filler will give a less smooth paper, but again, higher loadings could compensate

4. A coarse filler will be better retained

5. A coarse filler will require less size

6. A coarse filler will be more abrasive

7. A coarse filler will be less bright

*Properties of a coarse filler(4)

% fines than 2 μM	12
% coarse than 10 μM	22
% coarse than 20 μM	2
% brightness (Iso)	80

Cationic starches have been used to preflocculate the clay fillers. These starches are also used for dry strength improvement. A 5% addition of cationic starch to the clay filler prior to addition to the furnish with proper mixing and point of addition, can result in loadings 5 to 10% greater than papers of equal physical properties without clay preflocculation.(4) The scattering coefficient will be reduced in the aggregated clay than the untreated, but the increased loading can compensate for the sheet opacity reduction.(4) Increased density or reduced bulk is a main disadvantage of increasing the loading level, which is a characteristic that printers dislike.

Synthetic polymers such as polyacrylamids have also been shown to be effective for reducing the effective surface area of clay fillers. However, the precise control over the floc size is necessary to prevent the floc size from becoming larger than 75 .(4) In general, high molecular weight polymers (10^6) of low or neutral ionic charge give the best results and dosage rates are about 0.1% by weight on filler.(4)

Effect of Polypropylene Fibers

One method of regaining lost physical strength is to add low levels less than 15% of polypropylene fibers to the furnish and thermally fuse them together. Synthetic pulps are generally defined as very fine, highly branched, discontinuous, water dispersible fibers made from plastics.(5,6) These shouldn't be confused with staple fibers which are smooth rods of solid polymer.(5) The synthetic pulps are usually based on either high density polypropylene or polyethylene, with or without inorganic fillers.(6,10,11) These synthetic pulps should be refined in a disk type refiner to prevent "balling" up of the fibers, as happens in a Hollander type refiner.(8.9)

Synthetic pulps posses many characteristics that are desirable for this project. First, the pulps have very irregular surfaces with many crevices and an almost film-like nature. This irregular surface creates a very large surface area, typically 5-20 m^2/gm, whereas cellulose is usually less than 1 m^2/gm.(5,6) Also, because of the large surface area, the scattering coefficients are quite high, and the brightness is usually greater than 92%.(5.8)

Another advantage to using polyproplyene (PP) or polyethylene (PE) fibers in the furnish is to increase the drainage rate on the forming table. (6,7,8,9) This results in easier drying and potentially more production. Care must be taken to not use temperatures greater than the melting point of

polyethylene (165°C) in the last dryer cans.(6,8) Wet and dry strength resins also function normally as long as the synthetic pulps have not been modified to introduce caboxyl groups which will cause synergistic effects to occur.(6) If the furnish has dyes added, they will appear to be lighter in color than usually observed, but after fusing the web containing the polypropylene fibers, the color intensifies.(6,8) Retention of inorganic fillers increases with the addition of syntehtic fibers because of the large surface area, allowing higher filler loadings.(6) One disadvantage during the paper manufacturing, converting, and printing processes is that the web shouldn't be transferred over stationary metal parts at fast speeds. Localized high temperatures caused by friction can fuse tiny bits of polymer and cause it to adhere to the metal. Hercules, Incorporated has developed a teflon derivative tape that can be placed over these metal parts to help alleviate this problem.(9)

Unconsolidated or unfused papers used for printing and writing papers are higher in bulk compared to a similar weight sheet without any polypropylene, as polyethylene has 1.5 times the bulk of cellulose and polypropylene has two times as much. Also, the brightness and opacity are greater. Lighter weight papers can be made with caliper maintained even after calendering to high smoothness. Other useful properties include porosity, smoothness, wet strength, thermoplasticity, thermoformability, chemical inertness, dielectric properties, dimensional stability and some barrier properties. (6,7,8,9,10, 11) However, when the sheets are loaded with filler, the physical properties will decrease to levels below that of sheets without synthetic pulp addition.(6,9)

Thermally fusing or consolidating the sheet can significantly improve the physical propertie such as internal bonding. Care must be taken that the

sheet doesn't stick to the metal rolls during the fusion process. A second characteristic of fused sheets is that opacity is drastically reduced because of the melting polypropylene fibers. This can be overcome by the increased filler loadings, to some extent. If the fusion takes place without pressure, the physical properties can be achieved without losing bulk. However, by using pressure, even greater tensile and burst values can be developed. (5,6,9,)

Effect of Hot Supercalendering

Hot supercalendering is one method that can be used to thermally fuse the sythetic fibers. This will result in a sheet that is smoother, glossier, and have better printing properties. Studies have shown that by incorporating higher temperatures and lower pressures, better sheet properties can be developed with less bulk loss than if cooler temperatures and higher pressures are used.(12,13) Smoothness values remain constant as the temperature is incresed and pressure reduced. However, when the pressure was held constant, the smoothness increased with temperature.(12) Gloss also developed similar relationships. Sheet bulk naturally decreases as the calendering pressure increases. However, by using hot calendering techniques, bulk loss was reduced when compared to sheets with equivilent sheet properties supercalendered by cold supercalendering methods.(12) This is surprising to find bulk sensitive to both temperature and pressure. Brightness and opacity were found to sensitive to temperature and pressure, with opacity more sensitive.(12) The values were improved by using hot supercalendering methods. Even sheet printability was found to be improved and was more sensitive than either gloss or smoothness.(13) The benefits of improved sheet characteristics and the high temperature to fuse the synthetic fibers proved that hot

supercalendering was beneficial in the converting operation of the sheet. (12,13)

EXPERIMENTAL PROCEDURE

The experimental part of this project was conducted in two stages, the first being handsheet preparation and evaluation, leading to the second part with a machine trial on Western Michigan University's Pilot Plant Fourdrinier machine.

For the handsheets procedure, stock preparation was the first step. The cellulose component of the furnish consisted of 80% Espinola softwood for strength and runability and 20% Espinola hardwood for opacity, smoothness, and some dollar savings. The polypropylene fibers used were Lextar Pulpex H-231, which is bondable and available through Hercules, Incoporated (see Appendix 1 for properties).(14) Sixteen combinations of furnishes were tested and the combinations are listed in the following table.

TABLE I

Handsheet Furnishes

		% Total Filler			
		0	20	30	40
% Pulpex	0	X	X	X	X
	5	X	X	X	X
	10	X	X	X	X
	15	X	X	X	X

Each of sixteen furnishes was refined in the Mead Refiner according to Tappi Useful Method 221, to 400-350 CSF (see Appendix 2 for procedure).

In the proportainator of a Noble and Wood machine, the stock, clay (if any), Pexol size (0.5% based on solids), 1.5% alum, 1% latex (Dow XD-

30374.02), and 0.15% Reten 220 (see Appendix 3 for retention aid addition rate calculation). Handsheets were found on a Noble and Wood machine by using one-third of the headbox and maintaining a 4.5-5.0 pH. The target basis weight was 2.05 gm (OD) corresponding to a 32 lb/3300 ft^2.

Determining the optimum calendering conditions was accomplished by using handsheets with 5% pulpex and 30% filler, along with a second set of sheets with 10% pulpex and 20% filler. Four sheets from both groups were supercalendered at 200°F and 300, 600, 800, 1000 and 2000 pli. The supercalender was located at the Hercules Laboratory in Kalamazoo. It has seven inch diameter rolls, 42 fpm nip speed, the steel roll can be electrically heated to 450°F and the second roll is made of a resiliant plastic. Each sheet had four passes, always with the felt side next to the steel roll. Testing was conducted after the sheets were conditioned to 50% relative humidity and 72°F for 48 hours.

After analyzing the test results from these test results, the sixteen sets of handsheets were supercalendered at Hercules at 450 pli and 200°F. A limit of 200°F was used because of temperature limitations of the W.M.U. Pilot Plant supercalender. These sheets were also conditioned and tested in the same manner as the previous set of handsheets. The tests conducted were ash, basis weight, caliper, gloss, burst, tensile (1 cm/min), scott bond, tear, brightness, and opacity (see Appendix 4 for data).

Conditions for machine trial were based upon the results of the handsheet testing. Furnishes were selected and tested in the Table II.

The cellulose component was an 80/20 blend of Espinola solftwood and hardwood, as for the handsheets. Refining of the combined pulpex and cellulose was done in a Jones double disk at 2% consistency to 375 CSF. Clay was added to the storage chests after the stock was refined (see Appendix 4 and 5).

TABLE II

Machine Trial Furnishes

		% Filler		
		20	30	35
% Pulpex	5	X		X
	10		X	
	15	X		

During the trial, two clay loading levels were obtained for each of the four furnishes. The first loading was obtained by adding the clay to the storage chest and running the furnish on the W.M.U. Pilot Plant fourdrinier machine. Approximately halfway through the run of each furnish, another addition of 50% more clay was added to the machine chest. When the additional clay was added, the retention aid flow was increased by 50% to accomodate the increased system loading. During the machine trial, Run A represented the low clay addition, and Run B was for the increased clay loading.

For the machine trial, the same materials and addition order as the handsheets were followed. Pexol size was added to the first kettle at 0.5%, alum to the second kettle at 1.5%. The latex was also added to the second kettle at 1%. Retention aid was added to the feeder pipe at 0.12% and 0.18%. All addition rates are based on total solids, and only the retention aid flow was increased for the increased clay loading midway through each furnish run. Again, the basis weight target was 32 lb/3300 ft^2. This corresponded to a production rate of 131 lbs/hr and a speed of 100 fpm. Also, the headbox pH was 4.5-5.0 and H_2SO_4 was added to the feeder pipe to make adjustments.

After the paper from the W.M.U. Pilot Plant fourdrinier was manufactured, it was stored on the loading dock of the pilot plant 11 days before it was supercalendered. The W.M.U. Pilot Plant supercalender has eight nips,

allowing four polishing nips for each side of the paper web. The supercalender rolls were heated to 240°F (steel) and 214°F (cotton) and then half of the paper was supercalendered. The rolls were reheated, and the remaining stock was supercalendered. Samples were collected before and after supercalendering to allow comparisons of data. Supercalendering conditions are listed in Table III.

TABLE III

Supercalendering Conditions (W.M.U. Pilot Plant)

1000 pli	–	minimum value for stock
720 fpm		
240°F	–	steel rolls
214°F	–	Cotton rolls
8 nips used	–	4 for each side of web

The supercalendered rolls were sheeted to 8½" x 11" and conditioned to 72°F and 50% relative humidity for 48 hours before testing. The tests conducted were basis weight, ash, tensile (1 cm/min), Parker-Print Surf (roughness), caliper, brightness, opacity, gloss (75%), tear, burst, and Scott Bond.

Analysis of the burst and scott bond results resulted in the supercalendering of some machine sheets at Hercules. These sheets are listed in Table IV and were not previously supercalendered. The supercalendering conditions were 400°F and 1000 pli, and only one pass was used.

TABLE IV

Machine Sheets Hand Calendered at Hercules

		% Filler 20	% Filler 30
	5	A	B
% Pulpex	10		A
	15		A

Letters are run numbers

RESULTS AND DISCUSSION

The following results are generated by using the previously outlined experimental procedure. All test procedures were conducted according to the TAPPI methods and/or manufacturer instructions. Values given are averages and were obtained by testing at least ten samples from each set after the paper ws conditioned to 72^{o}F and 50% relative humidity. All of the testing was done at Western Michigan University's Paper Science and Engineering Department. Raw data averages for these tests are available in the Appendices.

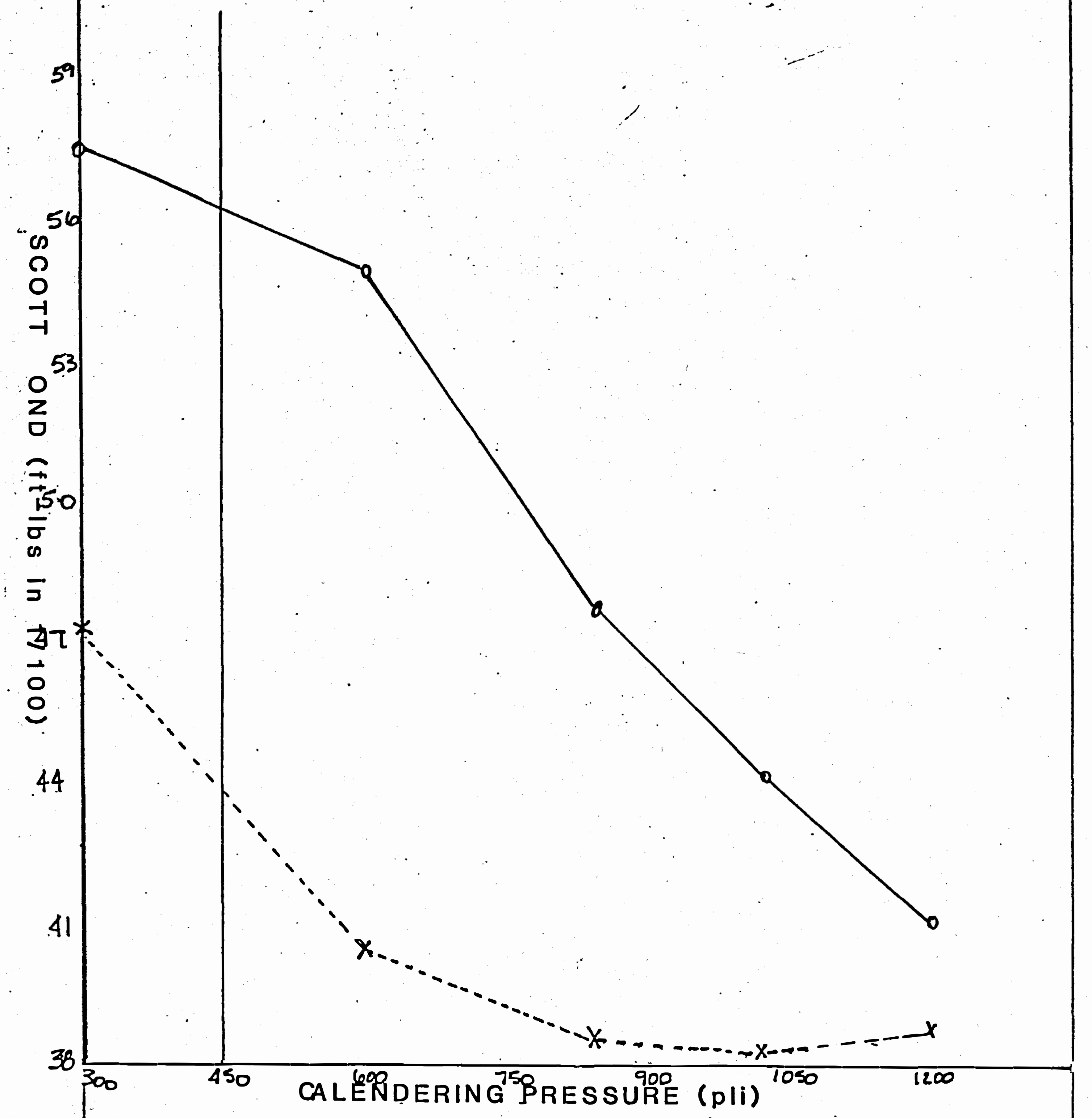
Determining the optimum calendering conditions for the handsheets was done by using the Hercules lab supercalender and analyzing Graphs 1-4 which are on the following pages. Burst and Scott Bond were the two strength tests that revealed the most information for strength vs. increasing calendering pressure. The trend of decreasing strength as calendering pressure increases, as seen in Tables I and II, may have been caused by the polypropylene fibers fracturing.(15) Also, the amount of time that the handsheet was in contact with the heated rolls in the nip, defined as nip retention time, was not long enough for a heat transfer to fully consolidate the pulpex. A trend of higher filler content having lower strength is indicated by Graph 2, confirming a result of Beazley Et.Al. A value of 450 pli was selected for handsheet calendering to reduce the amount of strength loss from pulpex fractionation.

Optical properties of gloss and opacity were also examined for selecting the optimum calendering pressure for handsheets. Graph 3 shows that optimum gloss was developed at 600 pli, and then decreased. Also, the higher loaded sheet developed more gloss than the less filled sheet, again confirming a conclusion of Beazley Et.Al. The decrease in gloss conflicts with Munch's

CALENDERING PRESSURE vs SCOTT BOND

X---X 65/5/30 Pulp/Pulpex /Filler

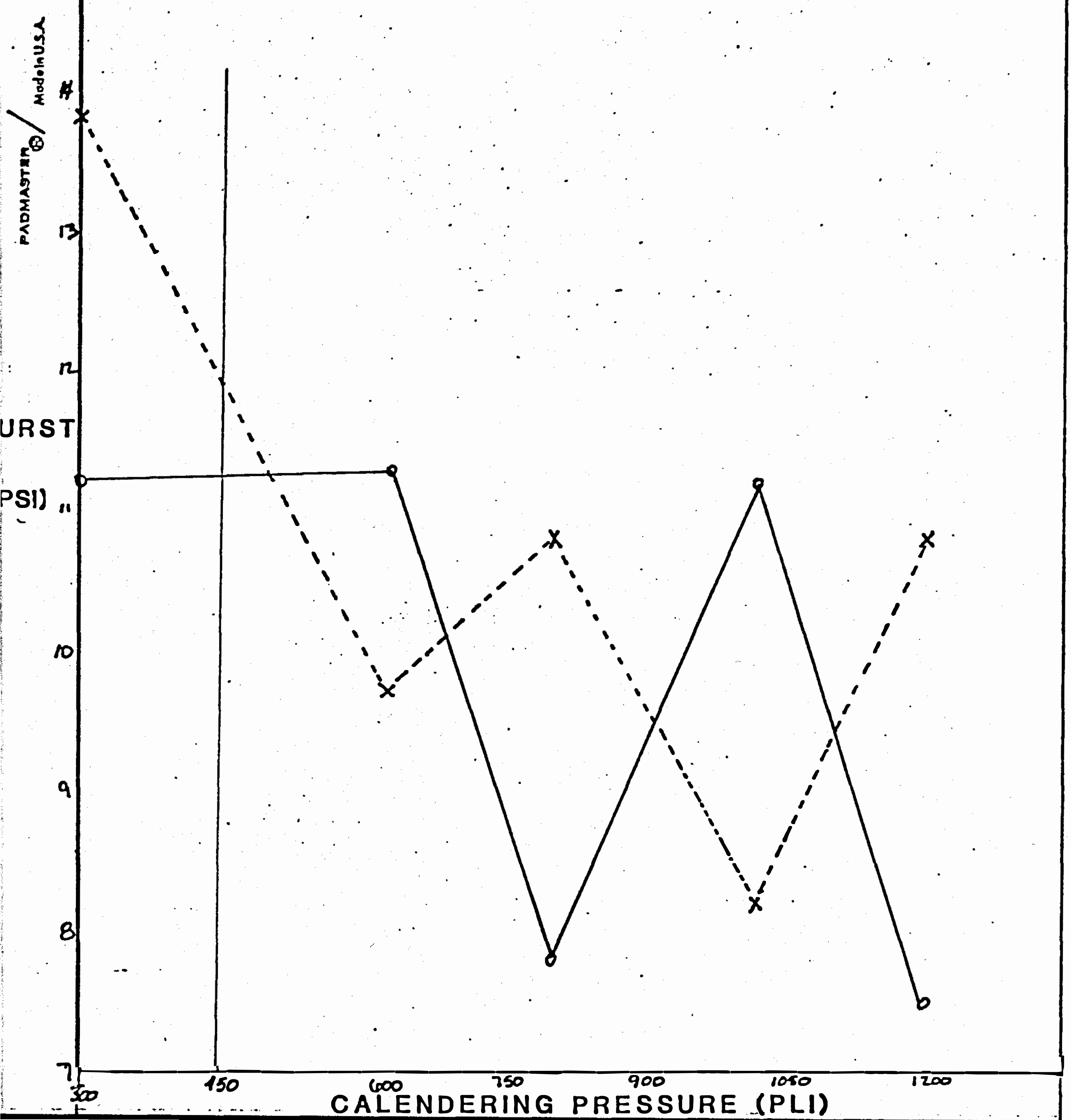
O---O 70/10/20 HERCULES LAB SUPERCALENDER



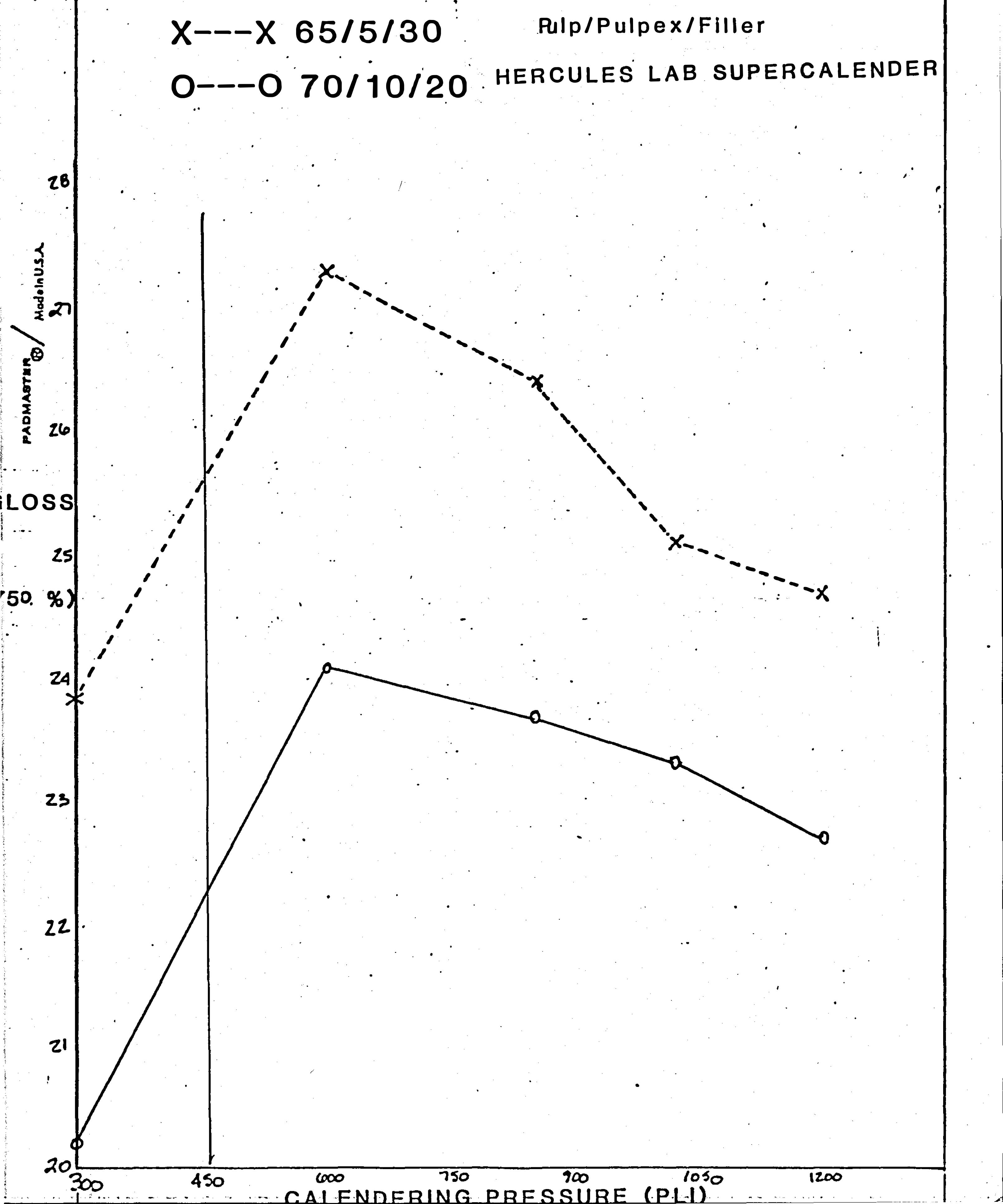
Calendering Pressure vs Burst

x---x 65/5/30 - Pulp/Pulpex/Filler

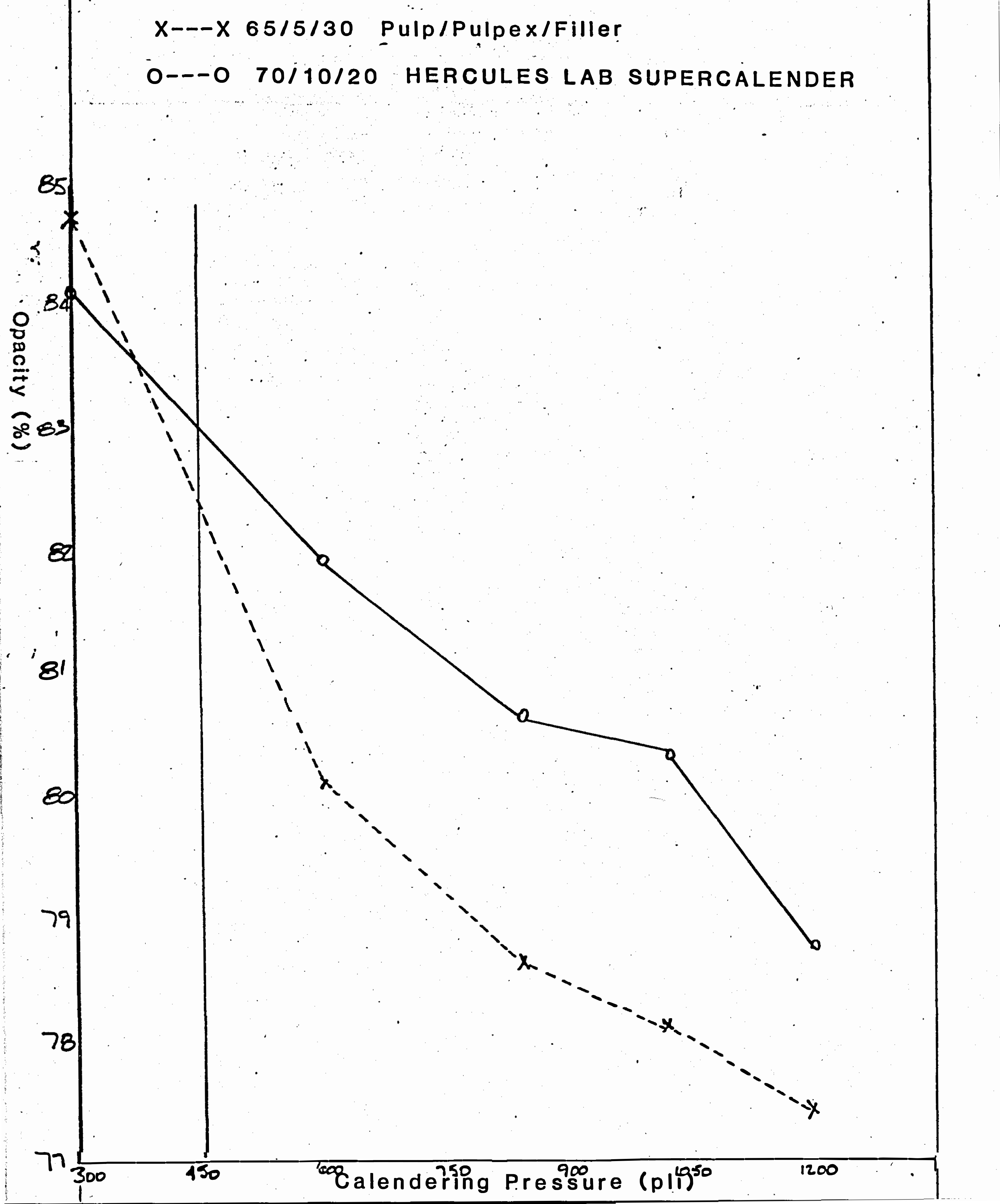
o—o 70/10/20 · HERCULES LAB SUPERCALENDER



Calendering Pressure vsGloss



CALENDERING PRESSURE vs OPACITY



results of increased gloss as pressure increases and may be due to the presence of the polypropylene fibers. Increasing the calendering pressure caused a decrease in opacity as stated by Munch Et.Al. and Moorelag. A note about the pressure increase; the sheet had an "orange peel" look to it as the sheets were consolidated, possibly indicating incomplete fusion of the polypropylene fibers. The basis weight for the 30% filled sheets were up to 33% less in basis weight than the 20% filled sheets, resulting in a lower opacity than the less filled sheets. Again, to reduce the opacity loss and get good gloss development 450 pli was selected as the optimum calendering pressure for the handsheets.

Tables V and VI show results from the handsheets after they were supercalendered at 200^{o}F, 450 pli and four passes on the Hercules lab supercalender. For strength analysis, burst and Scott Bond were analyzed because these tests best reveal the degree of internal bonding development of the polypropylene fibers. Table V definately shows that the filler is a deterrant to strength development, as seen by looking at the zero pulpex addition and the increasing filler rows. The loading caused a loss of approximately 85% bursting strength and 59% Scott Bond for the zero pulpex sheets. However, by

TABLE V

Burst (psi)

		% Filler			
		0	20	30	40
% Pulpex	0	4.6	2.4	1.8	1.0
	5	23.8	24.7	10.3	5.1
	10	21.4	9.0	5.3	4.2
	15	20.7	11.0	3.1	3.6

substituting 15% pulpex for cellulose, the strength loss was increased 41.4% for bursting strength, and 111% for Scott Bond. These numbers are from the zero pulpex, 40% filler values compared to 15% pulpex and 40% filler sheets. The Scott Bond results indicate that as pulpex values are increased, internal strength increases, when the sheets are fused. Also, that an increase of filler content reduces the internal strength.

TABLE VI

Scott Bond (ft-lbs in/1000)

		% Filler			
		0	20	30	40
% Pulpex	0	47.6	38.6	29.3	19.5
	5	55.2	47.1	41.8	37.3
	10	60.5	51.7	46.4	39.0
	15	63.2	54.8	47.6	41.1

Table VI shows some optical properties for the handsheets. Gloss increased by 12.9% by increasing the pulpex content as seen by examining the zero filler column against increasing pulpex quantities. Increasing filler content also increased gloss, confirming another conclusion of Beazley et.al., by 36%. However, at the 15% pulpex addition level, this increase was only 26%. This shows that the interaction of polypropylene fibers and clay filler has negative effects for internal strength.

Opacity does increase by 66% when increasing the filler content from zero to 40.0%. However, by only increasing the pulpex quantity with zero filler, the opacity remains essentially constant, which contradicts Moorelag and Rowe.(9,16) This may be due to only partially consolidating the pulpex

TABLE VII

Gloss

		% Filler			
		0	20	30	40
% Pulpex	0	17.8	20.3	22.8	24.2
	5	19.6	23.7	25.6	25.3
	10	18.6	21.7	24.8	26.1
	15	20.1	23.9	24.1	25.4

TABLE VIII

Opacity

		% Filler			
		0	20	30	40
% Pulpex	0	71.1	67.1	70.0	75.8
	5	65.5	72.7	80.6	79.1
	10	71.0	82.4	76.7	78.7
	15	71.4	83.0	79.0	81.5

fibers in the sheet because of the sheet nip retention time and degree of heat transfer.

Combining the analysis of the handsheets after using the Hercules lab supercalender, resulted in the selecton of the following sets of conditions, are listed in Table IX. Analysis of machine trial tests was done by comparing uncalendered and supercalendered sheets along with the varying furnishes which include the 50% increase loading for Run B for each furnish. Once again, the most informative strength results were the burst and Scott Bond tests. Opacity and gloss were used to evaluate the optical properties. Brightness and compressibility also were analyzed.(7)

TABLE IX

Machine Trial Furnishes

		% Filler		
		20	30	35
% Pulpex	5	X		X
	10		X	
	15	X		

TABLE X

Scott Bond

			% Filler	
			20 Low/High	30 Low/High
% Pulpex	5	Uncalendered	53.5/----	54.2/39.1
		Calendered	44.1/27.0	51.1/41.4
	10	Uncalendered		54.3/47.2
		Calendered		48.5/38.5
	15	Uncalendered	53.0/48.7	
		Calendered	52.7/44.4	

TABLE XI

Burst

		% Filler	
		20 Low/High	30 Low/High
% Pulpex 5	Uncalendered	6.10/----	3.40/3.40
	Calendered	5.90/5.40	3.10/3.00
% Pulpex 10	Uncalendered		4.30/4.00
	Calendered		4.50/3.90
% Pulpex 15	Uncalendered	4.60/3.70	
	Calendered	2.90/3.50	

Tables X and XI show the Scott Bond and burst values. In all cases, the addition of filler for part B of each run caused a strength reduction indicating that fillers are detrimental for strength development. Also, in all cases, by supercalendering the sheets, there was a strength reduction. This result is in contradiction of Kincannon and Moorelag.(8,9) Consequently, the polypropylene fibers were determined to be unconsolidated. Supercalendering of the sheets may have caused fracturing of the polypropylene fibers rather than consolidation, resulting in a weaker sheet.(15) This may be due to the nip retention time being too short for a heat transfer great enough to melt the polypropylene.(15)

Results in Table XII also show that supercalendering caused a reduction in strength further which indicates that the sheets had inconsolidated polypropylene fibers. Tear for the unsupercalendered sheets show tends of increasing values with increasing pulpex quantities. Increases as much as 24.3% were obtained. The large, surface area and irregular surface of the

TABLE XII

Tear

% Pulpex		% Filler: Machine Direction 20 Low/High	Machine Direction 30 Low/High	Cross Machine Direction 20 Low/High	Cross Machine Direction 30 Low/High
5	Uncalendered	39.2/----	26.3/29.6	47.2/----	26.4/32.8
5	Calendered	34.4/36.0	20.8/27.2	41.6/39.2	24.0/30.4
10	Uncalendered		39.2/36.8		36.8/40.0
10	Calendered		32.0/32.0		33.6/32.8
15	Uncalendered	40.8/38.4		43.2/40.8	
15	Calendered	35.2/31.2		37.6/33.6	

TABLE XIII

Opacity

% Pulpex		% Filler: 20 Low/High	30 Low/High
5	Uncalendered	82.1/----	83.1/87.7
5	Calendered	79.8/82.1	79.0/82.6
10	Uncalendered		85.6/87.9
10	Calendered		82.9/83.3
15	Uncalendered	85.7/86.3	
15	Calendered	82.4/82.5	

pulpex would most likely be the cause of this increase. Filler increases also caused a slight reduction of 6.1% in tear values, and not all tear values decreased with the 50% filler addition for part B of the furnish run.

Opacity values, as shown in Table XIII show a trend of increasing filler contents results in greater opacity. However, an increase of 62% of ash resulted in only a 5.5% increase in opacity (5% pulpex, 30% filler). Comparing the low clay levels (20.7% and 21.4% ash - 3.4% increase) and 5-15% pulpex sheets showed an increase of 4.4% opacity. This indication that unconsolidated polypropylene fibers aid in opacity development, which is in agreement with Kincannon and Rave.(8,6)

TABLE XIV

Gloss

			% Filler	
			20 Low/High	30 Low/High
% Pulpex	5	Uncalendered	6.4/----	7.7/7.5
		Calendered	18.4/22.0	16.5/19.5
	10	Uncalendered		6.3/6.7
		Calendered		20.3/24.1
	15	Uncalendered	6.6/6.7	
		Calendered	16.5/20.7	

Gloss values are similar when increasing the pulpex quantities from 5 to 15% and keeping the filler level constant. However, at 10% pulpex and 30% filler, there was an 18.2% drop in gloss for unsupercalendered sheets compared to the 5% pulpex sheet at a similar filler loading.

TABLE XV

Brightness

		% Filler 20 Low/High	% Filler 30 Low/High
% Pulpex 5	Uncalendered	82.1/-----	81.8/81.0
	Calendered	80.8/79.8	80.3/78.3
% Pulpex 10	Uncalendered		83.1/81.9
	Calendered		81.1/79.5
% Pulpex 15	Uncalendered	83.5/83.5	
	Calendered	82.9/81.1	

Brightness remains within ± 1 point of the mean of 82.4 for the unsupercalendered sheet at all filler levels. This is shown in Table XIV and indicates that filler brightness of 82 is the dominating factor in these highly filled sheets rather than the pulpex. Also, that synergistic effects between the two are minimal at high filler loadings.

The compressibility values show that at various pulpes levels and clay loadings the values remain constant. This is shown for both the uncalendered and calendered sheets. Sheet compressibility is not affected by the pulpex addition or increased filler loadings.

Because the Pilot Plant machine supercalendered sheets were unfused, some sheets that were made on the Pilot Plant machine and not supercalendered were supecalendered by hand at 400°F and 1000 pli on the Hercules laboratory supercalender through only one nip. Table XVII shows some test results compared to the equivalent machine supercalendered results. Examination of the sheets hand supercalendered showed an "orange peel" look which was caused

TABLE XVI

Compressibility (Parker Print-Surf)

		% Filler	
		20 Low/High	30 Low/High
% Pulpex	5 Uncalendered	1.16/----	1.16/1.19
	5 Calendered	1.15/1.20	1.18/1.19
	10 Uncalendered		1.15/1.15
	10 Calendered		1.12/1.18
	15 Uncalendered	1.16/1.19	
	15 Calendered	1.15/1.19	

$$\text{Compressibility} = \frac{\text{Roughness at } 10\text{kgf/cm}^2}{\text{Roughness at } 20\text{kgf/cm}^2}$$

with standard hard backing

= Rate with change of roughness with pressure

TABLE XVII

Comparson of Sheets Calendered on Western Michigan University's Pilot Plant Super Calender and Sheets Calendered on Hercules Lab Supercalender

	W.M.U. Machine 200°F	Hercules Lab 400°F	% Change
Burst	4.3	9.9	+129%
Scott Bond	44.5	53.8	+20.8%
Gloss	18.7	42.9	+130%
Opacity	81.9	78.3	-4.5%
Compressibility	1.18	1.17	-0.5%

Values are average from all four furnishes.

by the pulpex being only slightly fused and fractured in the nip.(15) Analysis shows that only opacity decreased, as expected, by Moorelag and Rave,(9,6) while the strength and gloss values increased. An increase up to 162% for burst shows that even fusing the sheet slightly will improve the internal strength of the sheets. Munch et.al. reported that gloss improves with increasing temperature, and these results concure with that result. Also, compressibility remained constant as both the filler level or pulpex content was increased. Results can be summarized as follows:

1. Increasing the supercalendering pressure causes a decrease in gloss, opacity and burst values

2. Increasing filler loading reduces sheet strength

3. Increasing polypropylene fibers causes an increase in Scott Bond

4. Gloss is improved by the combined addition of clay and polypropylene and hot supercalendering

CONCLUSIONS

This thesis showed that the degree of heat transfer for the fusing of polypropylene fibers is the determining factor for web consolidation. Because of the mechanical limitations of the equipment used, this time was too small and only partial fusing of the polypropylene fibers was obtained. Conclusions from the data generated can be listed as follows:

1. Partial fusing of polypropylene fibers can improve the Scott Bond value of a highly loaded sheet by 111%.

2. Unconsolidated pulpex has no synergistic effects with clay fillers for brightness, gloss and opacity values.

3. Supercalendering higher filled sheets containing pulpex results of up to a 18% loss of Scott Bond strength.

4. Additions of up to 15% pulpex without any filler added increased gloss by 12.9% when using the Hercules lab calender. By only adding 40% clay, the gloss was increased 36%. When 40% clay and 15% pulpex are combined and supercalendered, there is a synergystic effect, as the gloss was improved 46.6% over a sheet without any pulpex or clay.

RECOMMENDATIONS

Further work should encompass a change of consolidating methods. The degree of heat transfer must be increased to fully consolidate the pulpex. This could be done by using a larger diameter supercalender and/or using extended nip principle to allow a greater nip retention time. Another suggestion would be to use a supercalender that can be heated above 200°F. The 200°F limit is not only too low to fuse the pulpex, but it limits speed of the calender for nip retention time.

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APPENDIX 1

Typical properties of Pulpex H-231

Specific gravity = 0.90
Melting point, $^{o}C(^{o}F)$ = 165(329)

Fibrils

Length, mm	
Average	0.8 - 1.5
Maximum	2.5
Diameter, microns	20-40
Surface Area (BET,N_2), m^2g	5-10
Surface Behavior	hydrophilic
Bulk, cm^3/g	5.0

Materials

Pulp: Espinola Softwood and Espinola Hardwood

Hercules Pexal 277-400

Papermakers Alum

Englehard KWW Filler Clay

Dow XD-30374.02 Latex (SBR)

Hercules Reten 220 Retention Aid

H_2SO_4 (Concentrated)

Dispex (For Clay Dispersion)

APPENDIX 2

HANDSHEET FURNISH

For All Sets

Defiber 30 seconds in Waring Blender

Refine 50 seconds in Mead refiner

Transfer stock to proportionator (Noble & Wood)

1½% Alum = 2.56 ml of 12% Alum

0.35% Rosin = 2.87% of 3% solution

1.0% Latex = 0.52 ml of 47% solution

0.12% Retention Aid = 5.47 ml

Made Noble & Wood handsheets

Conditioned and tested

Set 1 (100-0-0)

24.6 dry gm stock = 19.68 gm SW x 1.15 = 22.63 wet SW
= 4.92 gm HW x 1.15 = 5.66 gm wet HW

Refined to 385 CSF

Set 2 (80-0-20)

24.6 gm stock x .08 = 19.68 gm stock = 15.74 gm SW x 1.15 = 18.11 gm wet SW
= 3.94 gm HW x 1.15 = 4.53 gm wet HW
4.92 gm clay x 10 = 4.92 gm clay added to proporator

Refined to 375 CSF

Set 3 (70-0-30)

24.6 gm stock x .07 = 17.22 gm pulp = 13.78 gm SW x 1.15 = 15.84 gm wet SW
= 3.44 gm HW x 1.15 = 3.95 gm wet HW
7.38 gm clay x 10 = 73.8 gm clay added to proportionator

Refined to 360 CSF

Set 4 (95-5-0)

24.6 gm x 0.60 = 14.76 gm stock = 11.81 gm SW x 1.15 = 13.58 gm wet SW
= 2.95 gm HW x 1.15 = 3.39 gm wet HW
9.84 gm clay x 10 = 98.4 gm clay to proportionator

Refined to 350 CSF

Set 5 (95-5-0)

24.6 gm x 0.95 = 23.37 gm stock = 18.70 gm SW x 1.15 = 21.50 gm wet SW
= 4.67 gm HW x 1.15 = 5.38 gm wet HW
1.23 gm pulpex x 1/.327 = 3.76 gm wet pulpex

Refined to 380 CSF

Set 6 (75-5-20)

24.6 x 0.75 = 18.45 gm stock = 14.76 gm SW x 1.15 = 16.97 gm wet SW
= 3.69 gm HW x 1.15 = 4.24 gm wet HW
6.15 gm pulpex x 1/.327 = 18.81 gm wet pulpex

Refined to 408 CSF

4.92 gm clay x 10 = 49.2 gm clay

For better clay retention: retention X4, size X2, latex X2

Set 7 (65-5-30)

80 gm stock x 5/70 = 4.71 gm pulpex x 1/.327 15.04 gm wet pulpex
74.29 gm cellulose = 59.43 gm SW x 1.15 = 63.22 gm wet SW
= 14.86 gm HW x 1.15 = 15.81 gm wet HW

Refined to 411 CSF

Added 34.3 x 10 gm of clay - used to make handsheets for determining optimum calendering conditions

For better clay retention: size X2, latex X2, retention aid X4

Set 8 (55-5-40)

24.6 gm 0.55 = 13.53 gm stock = 10.82 gm SW x 1.15 = 12.45 gm wet SW
= 2.71 gm HW x 1.15 = 3.11 gm wet HW
= 1.23 gm pulpex x 1/.327 = 3.75 gm wet pulpex
= 9.84 gm clay x 10 = 98.4 gm clay to proportionator

Refined to 377 CSF

For better clay retention: size X2, latex X2, retention aid X4

Set 9 (90-10-0)

50 gm x 0.9 = 45 gm pulp = 36.0 gm SW x 1.15 = 38.3 gm wet SW
= 9.0 gm HW x 1.15 9.57 gm wet HW
= 5.0 gm pulpex x 1/.327 = 13.16 gm wet pulpex

Refined to 407 CSF

Set 10 (70-10-20)

Used to determine optimum calendering conditions

80 gm x 10/80 = 10.0 gm pulpex x 1/.327 = 26.32 gm wet pulpex
= 70.0 gm pulpex = 56.0 gm SW x 1.15 = 59.56 gm wet SW
= 14.0 gm HW x 1.15 = 14.89 gm wet HW

REfined to 392 CSF

Added 20 x 7 gm clay to proportionator

For better clay retention: size X2, latex X2, retention aid X4

Set 11 (60-10-30)

50 gm stock x 1/7 = 7.14 gm pulpex 1/.327 19.31 gm wet pulpex
= 42.86 gm pulp = 34.29 gm SW x 1.15 = 36.48 gm wet SW
= 8.57 gm HW x 1.15 = 9.12 gm wet HW

Refined to 395 CSF

Added 7.38 x 7 gm clay added to proportionator

For clay retention: size X2, latex X2, retention aid X4

Set 12 (50-10-40)

50 gms x 1/6 = 8.33 gm pulpex x 1/.327 22.52 gm wet pulpex
= 41.67 gm pulp = 33.34 gm SW x 1.15 = 35.47 gm wet SW
= 8.33 gm HW x 1.15 = 8.86 gm wet HW

Refined to 364 CSF

Added 33.3 gm x 7 gm clay to proportionator

For better clay retention: size X2, latex X2, retention aid X4

Set 13 (85-15-0)

50 gms x 0.85 = 42.5 gm pulp = 34.0 gm SW x 1.15 = 39.10 gm wet SW
= 8.50 gm HW x 1.15 = 9.78 gm wet HW
= 7.50 gm pulpex x 1/.327 19.74 gm wet pulpex

Refined to 390 CSF

Set 14 (65-15-20)

50 gm x 15/80 = 9.38 gm pulpex x 1/.327 24.67 gm wet pulpex
= 40.63 gm pulp = 32.50 gm SW x 1.15 = 37.38 gm wet SW
= 8.13 gm HW x 1.15 = 9.35 gm wet HW

REfined to 370 CSF

Added 12.5 gm x 5 = 62.5 gm clay

For better clay retention: size X2, latex X2, retention aid X4

Set 15 (55-15-30)

50 gm x 15/70 = 10.71 gm pulpex x 1/.372 = 28.20 gm wet pulpex
= 39.29 gm pulp = 31.43 gm SW x 1.15 = 36.14 gm wet SW
7.86 gm HW x 1.15 = 9.04 gm wet HW

REfined to 374 CSF

Added 21.43 gm clay x 7.5 = 160.7 gm clay

For better clay retention: size X2, latex X2, retention aid X4

Set 16 (45-15-20)

50 gm x 15/60 = 12.5 gm pulpex x 1/.327 = 32.89 gm wet pulpex
= 37.50 gm pulp = 30.0 gm SW x 1.15 = 34.50 gm wet SW
= 7.50 gm HW x 1.15 = 8.63 gm wet HW

Refined to 334 CSF

Added 33.3 gm clay x 7 = 233.3 gm clay

For better clay retention: size X2, latex X2, retention aid X4

APPENDIX 3

RETENTION AID USAGE

To determine the amount of Hercules Reten 220, a highly charged cationic and high molecular weight retention aid, requird by the furnish, the following procedure was followed.

1. Place 70 od grams of furnish in a beaker. The furnish was 90% cellulose and 10% pulpex.

2. 30 grams od of Englehard KWW clay was added to the stock

3. The mixture was adjusted to 1.5% consistency.

4. A magnetic spin-bar was used to agitage the slurry.

5. A solution of 0.4% Reten 220 was titrated into the beaker until visible flocs were formed.

The average of three trials indicated that a level of 0.15% retention aid (based on the total solids) should be added for best results.

APPENDIX 4

HANDSHEET TEST VALUES FOR
OPTIMUM CALENDERING CONDITIONS

* Furnish	Calendering Pressure	Basis Weight	Ash (%)	Burst (psi)	Tear	Tensile (kg/in)	Scott Bond	Gloss (%)	Brightness	Caliper (mils)	Opacity
5/30	300	40.8	21.6	13.8	43.1	3.50	47.3	23.8	79.2	2.76	84.7
10/20	300	46.9	19.4	11.2	46.5	2.95	57.2	20.2	79.2	3.28	84.1
5/30	600	38.3	26.9	9.7	41.9	3.25	40.2	27.3	77.7	2.42	80.1
10/20	600	39.9	20.1	11.3	45.0	1.95	54.8	24.1	78.4	2.81	81.9
5/30	800	37.0	24.5	10.8	40.3	3.65	39.9	26.4	77.3	2.51	78.8
10/20	800	42.4	23.8	7.8	43.8	3.10	47.6	23.7	77.2	2.85	80.6
5/30	1000	33.1	19.6	8.2	38.6	3.45	38.6	25.1	77.2	2.16	78.1
10/20	1000	49.4	25.1	11.2	45.1	2.60	44.3	23.3	76.4	3.17	80.1
5/30	1200	38.5	24.8	10.8	38.6	2.10	39.4	24.7	76.6	2.45	77.4
10/20	1200	37.4	23.1	7.5	42.6	2.45	41.1	22.7	77.6	2.71	78.7

* Pulpex/Filler

APPENDIX 5

HANDSHEET TEST VALUES

Furnish	Basis Weight	Ash (%)	Burst	Tear	Tensile	Scott Bond	Gloss	Brightness	Opacity	Caliper
100/0/0	38.8	0.3	4.6	54.1	1.64	47.6	17.8	73.6	71.1	3.16
80/0/20	32.9	10.2	2.4	32.6	0.85	38.6	20.3	81.5	67.1	2.60
70/0/30	30.6	15.4	1.8	18.2	0.28	29.3	22.8	80.2	70.0	2.43
60/0/40	30.3	18.7	1.0	14.4	0.37	19.5	24.2	79.6	75.8	2.19
95/5/0	35.2	0.1	23.8	58.6	3.98	55.2	19.6	68.9	65.5	3.03
75/5/20	33.9	13.8	24.7	50.6	2.58	47.1	23.7	77.5	72.7	2.69
65/5/30	37.8	19.2	10.3	40.6	2.84	41.8	25.6	77.9	80.6	2.44
55/5/40	34.5	23.9	5.1	40.0	2.26	37.3	25.3	78.2	79.1	2.35
90/10/0	34.6	0.2	21.4	57.3	3.66	60.5	18.6	74.9	71.0	3.05
70/10/20	39.5	14.6	9.0	44.2	2.88	51.7	21.7	78.2	82.4	2.81
60/10/30	30.4	21.6	5.3	30.7	1.80	46.4	24.8	78.7	76.7	2.23
50/10/40	31.4	27.3	4.2	30.1	1.64	39.0	26.1	72.9	78.7	2.24
85/15/0	36.0	0.2	20.7	49.3	1.86	63.2	20.1	75.4	71.4	3.17
65/15/20	41.5	10.7	11.0	47.7	2.50	54.8	23.9	77.9	83.0	3.17
55/15/30	31.0	21.8	3.1	22.4	1.42	47.6	24.1	78.9	79.0	2.36
45/15/40	34.1	29.4	3.6	24.6	1.26	41.1	25.4	79.2	81.5	2.52

APPENDIX 6

MACHINE TRIAL CONDITIONS

Furnish

	(Pulp-Pulpex-Filler)		(Pulp-Pulpex-Filler)
Run 1A	65-5-30	Run 1B	57-4-39
Run 2A	65-15-20	Run 2B	59-14-27
Run 3A	61-10-30	Run 3B	62-9-39
Run 4A	75-5-20	Run 4B	68-5-27

Materials

HW - Espinola - 20%
SW - Espinola - 80%
Size - Pexol 277-400 0.5% at first kettle
Alum 1.5% at second kettle
Filler - Englehard KWW
Wet STrength - Dow Latex XD-30374.02, 1% at second kettle
Retention Aid - Hercules Reten 220 added at feeder pipe, 0.12% and 0.18%
Speed - 100 fpm
Production - 131 lb/hr
Basis Weight - 32 lb/ream (25 x 38 - 500)

Run Conditions

All runs will be at 32 lb/ream with a shake, dandy, and no size press. The headbox consistencies will be 0.5%.

Four furnishes will be used, all refined in the double disk to 375 CSF. The Pulpex will be refined with the cellulose and the clay will be added to the stock tank after refining. The stock will be refined and stored at 2% consistency.

Machine headbox pH will range from 4.5-5.0 and be controlled with H_2SO_4 in the feeder tube.

Each of the four furnishes will have two filler and retention levels. The first will have the filler already in the stock and the reten will be added to the first kettle at 0.12% based upon dry solids. The second part of each furnish run will consist of adding 50% more clay to the machine chest and increasing the retention aid flow by 50%.

The paper will be flagged when the target is reached or when the close conditions are met, and run for 5-10 minutes. Approximately 45 minutes of run time will be allowed for each furnish. The last run should have all of the stock run out to generate a good lead for threading and conditioning the supercalender.

APPENDIX 6

(Cont.)

<u>Hercules Hand Supercalender</u>

300-1000 pli
42 rpm
Electrically heated steel rup to 450°F
Plastic resiliant roll
One nip (4 or 1 pass used)
Felt side always next to steel roll

<u>Western Michigan University Pilot Plant Supercalender</u>

1000 pli
720 fpm
Steel Rolls - 240°F
Cotton Rolls - 214°F
8 nips - 4 polishing nips for each side

APPENDIX 7

MACHINE TRIAL FURNISH

<u>Run 1A & B (65-5-34)</u>

180 lbs. (in beater) x .65 = 117 lb. cellulose (bone dry)
= 93.5 lb. SW x 1.15 = lb. wet SW
= 23.4 lb. HW x 1.15 = 27.5 lb. HW
= 9.0 lb. pulpex (H-231) x 1/0.327 = 27.5 lb. wet pulpex

Added 70 lbs. clay to stock chest after refining for Run A

Added 17 lbs. and 30% solids to machine chest midway through run for Run B

Stock refined to 368 CSF in Double Disk

<u>Run 2A & B (65-15-20)</u>

180 lb. x 0.65 = 117 lb. fiber = 93.6 lb. SW x 1.15 = 110 lb. wet SW
= 23.4 lb. HW x 1.15 = 27.5 lb. wet HW
= 27 lb. pulpex = 27 x 1/.327 = 77.1 lb. wet pulpex

Refined to 362 CSF in Double Disk

Added 50 lbs clay to stock tank

Added 17 lbs. clay in 30% slurry for Run 2B at machine chest

<u>Run 3A & B (60-10-30)</u>

180 lbs. x 0.60 = 108 lb. cellulose = 86.4 lb. SW x 1.15 = 102 lb. wet SW
= 21.6 lb. HW x 1.15 = 25.4 lb. wet HW
= 18 lb. pulpex x 1/.327 = 51.4 lb. wet pulpex

Refined to 380 CSF in Double Disk

Added 50 lbs. clay to stock chest

Added 17 lbs. clay in 30% slurry to machine chest midway through run

<u>Run 4A & B (75-5-20)</u>

180 lbs. x 0.75 = 135 lb. cellulose = 108 lb. SW x 1.15 = 127 lb. wet SW
= 27 lb. HW x 1.15 = 31.8 lb. wet HW
= 91 lb. pulpex = 9 x 1/.327 = 25.7 lb. wet pulpex

Refined to 370 CSF in Double Disk

Added 50 lbs. clay to stock chest for Run A

Added 17 lbs. clay in 30% slurry to machine chest for Run 4B

All runs had 45 KW applied to refiner, 20 KW no-load

APPENDIX 8

MACHINE TRIAL RESULTS

	Ash Average	Test Values (%)
1A	29.9%	29.7, 30.1
1B	48.5%	49.3, 47.7
2A	20.7%	20.4, 21.0
2B	39.6%	39.6, 39.6
3A	26.8%	26.5, 27.1
3B	27.5%	26.4, 27.2
4A	21.4%	21.2, 21.6
4B	28.9%	28.3, 29.4

Ash Correction Factor (.876)

Machine First Pass Retention

1A	HB Consistency	0.47%
	1st Tray Ash	73.1%
	FPR	47.7%
1B	HB Consistency	0.51%
	1st Tray Ash	78.4%
2A	HB Consistency	0.49%
	1st Tray Ash	67.4%
	FPR	49.6%
2B	HB Consistency	0.50%
	1st Tray Ash	57.4%
	FPR	51.3%
3A	HB Consistency	0.48%
	1st Tray Ash	69.9%
	FPR	51.6%
3B	HB Consistency	0.52%
	1st Tray Ash	72.2%
	FPR	50.9%
4A	HB Consistency	0.53%
	1st Tray Ash	66.1¢
	FPR	53.1%
4B	HB Consistency	0.48%
	1st Tray Ash	72.2%
	FPR	49.6%

APPENDIX 9

MACHINE TRIAL RESULTS

Furnish	Tensile kg/in	Parker Print-Surf *	Basis Weight 3300ft^2	Caliper (mils)	Brightness	Opacity	Gloss (75%)	Tear MD/CD	Burst	Scott Bond
1AU	0.88-CD 2.17-MD	50.7 43.6	26.4	2.12	81.8	83.1	7.7	26.3 26.4	3.4	52.4
1AC	1.09-CD 1.77-MD	31.7 26.9	26.9	1.72	80.3	79.0	16.5	20.8 24.0	3.1	51.1
1BU	1.01-CD 2.08-MD	46.9 39.4	33.8	2.35	81.0	87.7	7.5	29.6 32.8	3.4	39.1
1BC	1.17-CD 1.86-MD	31.3 26.4	31.3	1.87	71.3	82.6	19.5	27.2 30.4	3.0	41.4
2AU	1.59-CD 2.62-MD	54.6 47.0	30.6	2.78	83.6	85.7	6.6	40.8 43.2	4.6	53.0
2AC	1.61-CD 2.16-MD	3.33 28.9	30.4	2.38	82.9	82.4	16.5	35.2 37.6	3.9	52.7
2BU	1.18-CD 2.29-MD	44.6 37.5	32.6	2.7	83.5	86.3	6.70	38.4 40.8	3.7	48.7
2BC	1.17-CD 1.51-MD	29.9 25.1	31.3	2.18	81.1	82.5	20.7	31.2 33.6	3.5	44.4
3AU	1.53-CD 2.39-MD	53.9 46.7	30.7	2.63	83.1	85.6	6.3	43.0 36.8	4.3	54.3
3AC	1.35-CD 3.02-MD	29.9 25.4	31.8	2.17	81.1	82.9	20.3	32.0 33.6	4.5	48.5
3BU	1.21-CD 2.40-MD	29.9 34.8	34.2	2.72	81.9	82.9	6.7	36.8 40.0	4.0	47.7

MACHINE TRIAL RESULTS
(Cont.)

Furnish	Tensile kg/in	Parker Print-Surf *	Basis Weight $3300ft^2$	Caliper (mils)	Brightness	Opacity	Gloss (75%)	Tear MD/CD	Burst	Scott Bond
3BC	1.90-CD	30.9	35.5	2.12	79.5	83.3	24.1	32.0	3.9	38.5
	2.35-MD	26.1						32.8		
4AU	2.01-CD	55.7	31.3	2.65	82.1	82.1	6.4	39.2	6.1	53.5
	3.35-MD	48.1						47.2		
4AC	1.60-CD	34.1	31.2	2.17	80.8	79.8	8.4	34.4	5.9	44.1
	3.25-MD	29.7						41.6		
4BC	2.15-CD	32.3	34.7	2.22	79.8	82.1	22.0	36.0	5.4	27.1
	2.76-MD	27.0						39.2		

* = Wire side down
10 kgf/cm^2
20 kgf/cm^2
(all values divided by 10)

Number = furnish or run #
A or B = high or low filler content
U or C = uncalendered or calendered

APPENDIX 10

MACHINE TRIAL TEST STANDARD DEVIATIONS

Run*	Tensile CD/MD	Parker Print-Surf	Basis Weight	Caliper	Brightness	Opacity	Gloss	Tear CD/MD	Burst	Scott Bond
1AU	0.06 0.19	0.25 0.20	0.19	0.04	0.34	1.00	0.10	2.19 1.97	0.22	4.12
1AC	0.05 0.19	0.16 0.12	0.14	0.08	0.27	0.67	0.26	2.83 1.79	0.22	1.45
1BU	0.04 0.33	0.09 0.13	0.01	0.05	0.18	0.47	0.60	1.79 2.19	0.22	6.35
1BC	0.07 0.40	0.13 0.11	0.71	0.15	0.17	0.78	1.10	2.19 3.35	0.0	4.48
2AU	0.07 0.20	0.44 0.35	0.22	0.15	0.31	1.70	0.61	1.79 1.79	0.55	1.22
2AC	0.14 0.25	0.25 0.16	0.45	0.15	0.21	1.10	1.07	2.19 1.79	0.42	7.96
2BU	0.04 0.10	0.22 0.19	0.60	0.01	0.29	0.38	0.17	3.35 2.19	0.27	4.15
2BC	0.05 0.36	0.18 0.11	0.76	0.10	0.22	1.07	0.85	3.58 1.79	0.35	7.81
3AU	0.08 0.20	0.55 0.54	0.48	0.05	0.29	0.89	1.04	1.79 1.79	0.45	8.24
3AC	0.09 0.32	0.07 0.11	0.22	0.08	0.22	1.25	0.75	2.19 2.83	0.35	2.65
3BU	0.12 0.14	0.33 0.26	0.35	0.08	0.43	1.16	0.93	2.83 3.35	0.35	3.50
3BC	0.06 0.15	0.23 0.29	0.60	0.19	0.14	1.32	0.82	1.79 0.0	0.42	5.80
4AU	0.02 0.20	0.36 0.30	0.62	0.10	0.33	0.89	0.31	7.16 3.35	0.42	3.21
4AC	0.09 0.27	0.12 0.11	0.53	0.10	0.20	1.29	0.17	2.19 3.58	0.42	5.20
4BC	0.26 0.24	0.11 0.08	0.31	0.08	0.29	1.12	1.37	5.93 4.00	0.65	10.0

U = Uncalendered   C = Calendered   A = Lower Filler Content   B = Higher Filler Content
Parker Print-Surf Values Are 10 kgf/cm^2 and 20 kgf/cm^2 for the Standard Backing (Wire Side Down)

APPENDIX 11

MACHINE CONDITIONS

Run	1A	1B	2A	2B	3A	3B	4A	4B
Headbox flow	55	55	53	53	54	54	55	5
Wire speed	100	100	100	100	100	100	100	100
Reel speed	106	105	105	107	106	105	106	106
Couch Vacuum	15	15	15	15	15	15	15	15
1st Pressure Front/Back	45/45	45/45	45/45	45/45	45/45	45/45	45/45	45/45
2nd Pressure Front/Back	44/42	44/42	44/42	44/42	44/42	44/42	44/42	44/42
Temperature 1st Dry	130°F	135°F	130°F	133°F	135°F	135°F	135°F	133°F
Temperature*	190	190	195	190	195	190	190	185
Temperature**	205	205	210	205	205	200	200	200
Nips	3	3	3	3	3	3	3	3
% Moisture	3.5	4.0	3.8	4.0	4.2	4.0	2.9	3.9

* = First Dryer Section
** = Last Dryer Section

Additive Flow Rates

Size:	165 ml/min	(3% solids)
Alum:	125 ml/min	(12% solids)
Latex:	100 ml/min	(10% solids)
Reten 220:	12 ml/min and 18 ml/min	(1% solids)

APPENDIX 12

MACHINE SHEETS HAND CALENDERED

Basis Weight	Burst	Tensile	Gloss	Tear	Scott Bond	Caliper	Opacity	Brightness	Parker Print-Surf *10/20
33.8	6.7	2.47-CD 5.35-MD	43.5	22.6-MD 28.1-CD	45.1	1.77	78.3	75.4	27.5 23.3
30.6	10.2	3.72-CD 5.41-MD	38.4	31.8-MD 34.3-CD	58.2	2.43	77.1	79.7	28.1 24.0
30.7	9.7	4.11-CD 6.08-MD	47.2	29.6-MD 31.2-CD	55.8	2.09	81.4	79.0	24.9 21.5
31.3	13.1	3.93-CD 5.86-MD	42.8	30.9-MD 37.5-CD	57.1	2.22	76.2	79.5	29.0 24.6

1000 pli, 400°F, One Pass on Hercules Lab Supercalender
*10/20 = 10 and 20 kgf/cm^2 (Roughness in), Divide Values by 20