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An Analysis of Chemithermomechanical Pulp (CTMP) in the Production of Rotogravure Paper

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AN ANALYSIS OF CHEMITHERMOMECHANICAL PULP IN THE PRODUCTION OF ROTOGRAVURE PAPER

BY

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FOR
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PAPER 473: SENIOR DESIGN PROBLEM II
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I also appreciate the donations of pulp from Dryden and Tembec, and chemicals from Pfizer, Hercules and Staley.

Also I would like to thank my thesis advisor, Dr. Ellsworth Shriver, for his encouragement and suggestions during this thesis.

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SUBJECT PAGE

AN ANALYSIS OF CTMP IN THE PRODUCTION OF ROTOGRAVURE PAPER

INTRODUCTION:

Current trends in the printing industry are shifting towards rotogravure printing processes. Today, rotogravure printing is responsible for 20% of the printing industry and is growing rapidly. The printing industry is moving towards rotogravure processes for high print quality for long run jobs.

The most commonly found examples of the rotogravure printing process are: "cheaper" catalogues, periodicals, tabloids, directories, newspaper inserts and the "Sunday supplement". Some of America's most popular magazines, for example, Reader's Digest, TV Guide, Better Homes and Gardens, Women's Day and many others are printed using rotogravure processes (1).

As the main supplier to the printing industry, the paper industry should be aware of current trends in printing. Since the demand for rotogravure paper is increasing with the increase in gravure printing, the paper industry should make an attempt to find an optimal sheet at the lowest possible production cost. If an optimum gravure sheet were found, gravure printers could produce higher quality print. An increase in the print quality of rotogravure sheets would please and encourage advertisers, thus encouraging production rates.

OBJECTIVE:

The primary objective of this thesis is to produce an optimal rotogravure paper using a CTMP (chemithermomechanical pulp) and Kraft furnish. Previous work done by Devendra Kumar Srivastava, (for his Masteral thesis, at Western Michigan University Department of Paper and Printing Science and Engineering) has shown that a suitable commercial Supercalendered Grade B paper can be produced using a Kraft and CTMP furnish. However, his thesis did not attempt to optimize the Kraft/CTMP furnish ratio, he used only 50% Kraft and 50% CTMP furnishes (2). This thesis will analyze the effects of varying the Kraft/CTMP furnish ratio, to produce the most optimal rotogravure sheet, both physically and economically.

After producing the paper, the secondary objective of this thesis is to supercalender the paper on the pilot plant supercalender in McCracken Hall. Next, the supercalendered sheet will be printed on the pilot plant rotogravure press in Welborn Hall.

LITERATURE SURVEY

ROTOGRAVURE PRINTING PROCESSES:

History:

The rotogravure printing process, as we know it today, was developed approximately one hundred years ago. But the roots of rotogravure printing extend back to intaglio printing. The first intaglio prints were made in approximately 1450. Intaglio and rotogravure processes both operate on the same principles of technology: etching the image into a transferring mechanism.

The technology of rotogravure printing became most popular following World War II in Germany and Western Europe. After the war, the destroyed and damaged letterpress printing presses were replaced with rotogravure presses. In the United States printing technology was slower to change from letterpress to rotogravure because the letterpress presses were gradually replaces as they wore out. Rotogravure printing is also referred to as gravure, photogravure or heliogravure (4).

Printing Technology:

In a rotogravure printing press the ink is transferred to the substrate from recessed cells in the rotogravure printing cylinder. As Figure 1 and 2 show, the substrate passes between the nip of the etched gravure cylinder and a rubber impression cylinder. Pressure and capillary action within the nip and immediately following it transfer the ink onto the substrate.

Figure 1 (3):

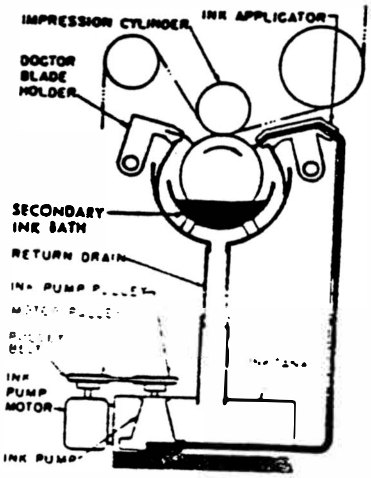
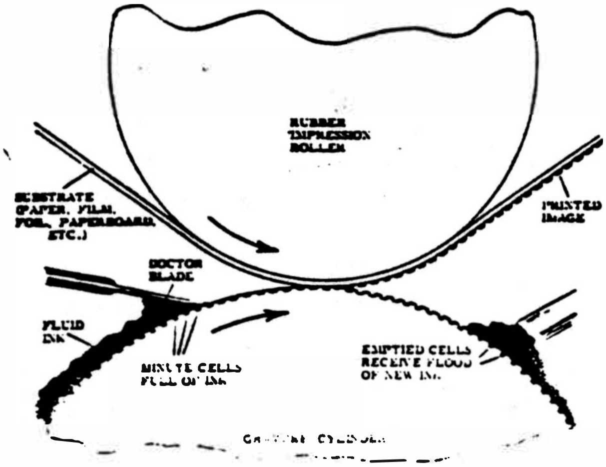


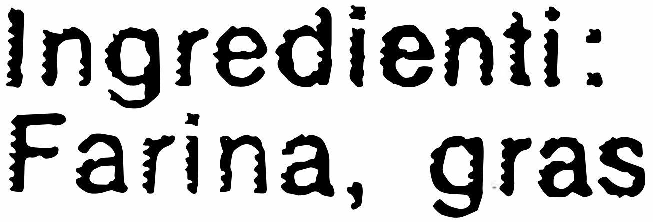
Figure 2: (3)



The rotogravure cylinder is rotated in a pan of ink, or the ink is sprayer onto the cylinder, to put the ink into the recessed cells. A doctor blade, prior to printing, is used to scrape off the excess ink from the surface of the gravure cylinder. Although other application methods are used, the roll and doctor blade is the most common.

Rotogravure presses are continuous web fed. Each gravure cylinder can apply only one color of ink to the substrate. For multi color prints several gravure cylinders are required. The cylinders are placed in series, with drying between each ink application. Enlargements of rotogravure printing illustrate the characteristic "dot" cell pattern of the rotogravure cylinder (see Figure 3). Low viscosity inks are used for easy cell filling and transferring (3).

Figure 3: (3)



Advantages and Disadvantages of Rotogravure Printing:

Gravure printing is used for packaging, publication and specialty printing. It can be used on several substrates including: paper, paperboard, corrugated board, foil or plastic products (5).

Advantages of the rotogravure printing process include:

- -Simplest printing process, fast press set-ups
- -Operates at high speeds, up to 45,000 impressions per hour, typically higher than flexographic and offset.
- -Excellent printing quality, high print fidelity
- -Long life of impression cylinders
- -Excellent color and ink density, even with low density papers.
- -Economical for long runs
- -Most consistent ink lay down, same cell volume every time (3,5).

The major disadvantages of the gravure printing process is the cost of the printing cylinder and the length of time it takes to create a cylinder. The high cost of the cylinder requires that it be used for long runs (above 500,000 impressions) or they are not economical. New developments in the production of gravure cylinders are aimed at computerized automation of the cylinder engraving process. Computerized automation would reduce both the length of time it takes to create a cylinder and its price (6).

Requirements of Gravure Printing:

The gravure process is a continuous web fed process, requiring a smooth, low porosity basestock with uniform formation and good runnability. Rotogravure presses demand a smooth sheet so that the ink "dots" may transfer onto the surface. If the sheet is too porous the ink will migrate into the sheet and will not be seen. Missing dots on a print are viewed as poor print quality. The continuous web must have good runnability., enough physical strength to make it through the press without breaking. Uncoated supercalendered paper is most commonly used on rotogravure printing presses (7).

UNCOATED SUPERCALENDERED PAPERS

Grades:

There are currently two main grades of uncoated supercalendered papers: Supercalendered Grade A (SCA) and Supercalendered Grade B (SBA). SCA is a highly filled sheet (up to 30% filler) that competes with light weight coated grades (LWC). SCB is a lower quality sheet than SCA, and typically contains less than 10-15% filler. SCB is considered a "high class newspaper". Table 1 lists the quality data for both SCA and SCB (2,4).

Table 1: (2) Quality Data for SCA and SCB.

Particular	SCA	SCB
Basis Weight (g/m2)	60	52
Density (g/cm3)	0.9-1	0.8-0.9
Brightness, % ISO	68	65-68
Opacity %	96	95
Sheffield Roughness (ml/min)	40	50-60
Paper Gloss %	25-35	20-30
Gravure Print Gloss %	35-40	25-35
Ash, %	20-30	6-12

Furnish:

To date, chemical pulp represents 20-35% of the furnish in supercalendered grades. The remainder of the fiber content of the sheet is made up of high yield mechanical pulps that impart the required smoothness and opacity on the sheet. The chemical pulp in the furnish generally increases the paper strength properties, runnability, drainage and linting but decreases opacity. The low yield chemical pulps constitute the largest portion of the furnish cost (2).

The fibers of the supercalendered furnish are often replaced by fillers because the fillers are less expensive than the fibers. The fillers add opacity, brightness and reduce the porosity of the sheet. When fillers are added the sheet strength is reduced, thus requiring more chemical pulp in the furnish.

Commercial Rotogravure Furnishes:

During the month of October three samples of the Sunday supplement to the Kalamazoo Gazette entitled "USA WEEKEND" were collected and tested. All tested were done in accordance to Tappi Standards. The results from the tests are shown below in Table 2. Color analysis on an Lab* scale showed that the sheet was slightly green and significantly yellow. Brightness and Opacity values fall below the standards for supercalendered grades found in Figure 3. However, these tests were performed on highly printed surfaces. It was difficult to get an unprinted area to test for optical properties. The printing on the pages could have influenced the opacity and brightness values.

Table 2: "USA WEEKEND", Kalamazoo Gazette Sunday Supplement Quality Test Data.

Basis Weight	51.33 g/m2
Density	0.66 g/cm3
Brightness, ISO	50.84 %
Opacity	76.68
Sheffield Smoothness	115.45 Sheffield Units
Caliper	3.05 mils

Furnishes using TMP:

During the mid 1970's, uncoated supercalendered paper producers began investigating the possibilities of replacing some of the groundwood in the furnish with TMP (thermomechanical pulps). TMP has higher strength properties than groundwood pulps, thus allowing the amount of chemical pulp in the furnish to be reduced. Reducing the amount of chemical pulps in the furnish is very important because the low yield chemical pulps constitute the largest portion of the furnish cost. The increased mechanical pulp content of the sheet also enhances the printability of the sheet (8).

Table 3 summarizes the results of a comparison of Groundwood and TMP pulps made in Saugrugsbrugs, Halden, Norway in 1975.

TABLE 3: A comparison of Groundwood and TMP properties (9).

	Groundwood	TMP
Freeness (ml)	70	70
Drainage Time (sec)	2.00	1.67
Sommerville Shives (%)	0.41	0.09
Bauer McNett >30 (%)	16.9	32.8
<200 (%)	31.2	28.7
Density (kg/m3)	362	368
Tensile Index (kNm/kg)	25.5	29.4
Elongation (%)	2.1	2.5
Tear Index (Nm2/kg)	3.7	5.8
Brightness (%)	60.7	60.1
Scattering Coef (m2/kg)	67.1	63.3

Table 4: (9)

TMP/Groundwood/Kraft furnish trials run at Saugbrugsforeningen, Halden, Norway.

Furnish	TMP	0	20	40	60
	GWD	80	65	47.5	30
	Kraft	20	15	12.5	10
Freeness, CSF (ml)		115	97	92	90
Drainage Time (sec)		1.44	1.56	1.61	1.63
Dryness at couch (%)		26.0	26.7	26.6	27.1
Wet Strength @ 25% (N/m)		88.0	90.3	89.0	92.9
Dryness after presses (%)		43.8	45.0	45.6	47.3
White Water Cons (g/L)		4.44	4.52	4.42	4.60
Density (kg/m3)		943	926	926	926
Tensile Index	MD	25.1	27.9	29.2	32.0
(kNm2/kg)	CD	13.1	14.8	18.1	19.9
Elongation (%)	MD	0.88	0.84	0.85	0.88
Tear Ind.(Nm2/kg)	CD	3.8	3.8	3.5	3.9
Burst Index (MN/kg)		1.3	1.3	1.3	1.5
Ash Content (%)		19.1	19.1	19.2	18.2
Opacity		92.6	93.8	94.6	95.2
Brightness (%)		66.1	66.0	65.3	65.1
Parker Print Surf	TS	2.05	1.95	1.90	1.85
(um)	WS	2.00	1.85	1.90	1.80
Bendsten	TS	26	28	28	26
(ml/min)	WS	28	28	30	28
Porosity (ml/min)		78	75	68	68
Oil Absorption	TS	9.5	10.0	9.0	9.0
(g/m2)	WS	10.0	11.5	10.0	9.5
Gloss Hunter	TS	26	28	28	26
	WS	27	27	27	28
Print Gloss	TS	12	15	16	12
(33 um)	WS	11	13	12	13
Blackness	TS	98	100	99	98
Contrast (33um)	WS	94	97	94	93
Print through	TS	4.3	5.0	4.0	4.0
(33 um)	WS	4.8	4.7	4.5	4.4
Printing	TS	17	23	25	26
Smoothness	WS	13	17	18	23

The results of the comparison between groundwood and TMP encouraged the Saugrugsbrugs mill to runs some trials varying the furnish ratios between groundwood, TMP and chemical pulps. The results of the trials are shown in Table 4. The trials showed that furnishes containing TMP could reduce the required amount of chemical pulps, without hurting the strength properties of the sheet (9). As Table 4 indicates, there are a wide variety of furnishes being used in the production of uncoated supercalendered papers. However, it is worth noting that the furnishes containing the highest percentages of TMP also contain the lowest amounts of chemical pulp.

Table 5: Current commercial furnishes of uncoated supercalendered papers (8, 10, 11, 12, 13).

Pulp	MILL A	MILL B	MILL C	MILL D	MILL E
Groundwood	38 %	--	--	38 %	--
TMP	42 %	84 %	60-75 %	15 %	86 %
Kraft	20%	16 %	25-40 %	47 %	14 %

CHEMITHERMOMECHANICAL PULPS

WHY NOT CTMP?:

After many successful trials in the 1970s, TMP has become an integral part of most uncoated supercalendered furnishes. Like TMP, CTMP presents another alternative to current furnishes. Replacing current mechanical pulps with CTMP gives the sheet improved runnability and printabilty. CTMP has a lower shive content, higher brightness and higher strength than TMP and groundwood. Because CTMP has higher strength properties than other mechanical pulps, more chemical pulps in the furnish can be replaced. Removing a portion of the chemical pulp in the furnish can significantly reduce the production cost of the paper, increase opacity and increase bulk. Due to this increased bulk, stiffness and opacity, sheets with lower basis weights can be produced (2).

The results of an extensive literature search indicate that a few mills have considered incorporating CTMP into their uncoated supercalendered furnish but no data is available yet. The purpose of this thesis will be to present data on CTMP/Kraft SC papers, either successful or unsuccessful. Trends in TMP performance for SC grades indicate that CTMP should also perform satisfactorily.

CTMP Pulping Technology:

CTMP is a high yield pulp that typically produces 90-95% yield. In chemithermomechanical pulping 2-4% sodium sulfite is added to the woodchips either before or after presteaming of the chips. The woodchips are presteamed at temperatures above 100 degrees Celsius. After the chemical addition and presteaming, the chips are refined in two stages. The primary refining stage is done at temperature above 100 degrees Celsius and the secondary refining stage is done at atmospheric conditions. Both stages of refining are most typically done in disc refiners (14).

SUPERCALENDERING UNCOATED PAPERS

A supercalender is a series of alternating hard steel rolls and cotton rolls. As the web travels between the nips of each of the rolls, the soft cotton rolls deform at the nip, creating friction causing a polishing effect on the sheet of paper.

Supercalendering compresses and densifies the paper, reducing caliper. The densified paper creates a more uniform printing surface. Smoothness,gloss and printability increase with supercalendering and opacity and brightness decrease (15). Several variables influence the supercalendering action, they include: the pressure and temperature of the supercalender rolls, the moisture content of the enterring sheet and the machine speed (which determines the dwell time the paper will spend in the nip) (16).

Uncoated SC grades are more common in Europe than North America, but the supercalendering conditions used in both continents are very similar. Table 6 lists the supercalendering configurations and operating conditions of typically mills in both Europe and North America.

Table 6: Supercalendering Configurations and Conditions for SCA and SCB in Europe and North America (16).

	SCA		SCB	
	E.	N.A.	E.	N.A.
Rolls				
# in stack	12	12	10-12	10
Hardness (Shore D)	86-87	89-90	86-87	89-90
Filler Material	cotton & wool	cotton	cotton & wool	cotton
Calendering Conditions				
Speed (m/min)	450-850	500-800	600-850	800-975
Linear Load (kN/m)	280-300	280-315	200-280	200-280
Temp (C)	90-110	90-115	85-110	85-110
Steam Showers	yes	yes	yes	yes
Sheet Properties				
Moisture in (%)	8-10	8-9	8-10	8-9
Moisture out (%)	5.5	5.5	5.5	5.5
Brightness ISO (%)	66-72	66-72	60-68	60-68
Smoothness (PPS10)	1.4-1.6	1.4-1.6	1.6-2.0	1.6-2.0
Hunter Gloss (%)	30-40	30-40	25-30	25-30

EXPERIMENTAL DESIGN

PHASE I:

The first phase of this thesis will consist of a pilot plant papermachine run at the Department of Paper and Printing Science and Engineering, Western Michigan University, Kalamazoo, Michigan. The papermachine run will hold all machine parameters and additive conditions constant and change only the fiber furnish. Six furnishes will be run, they are:

(1) 100% Kraft
(2) 80% Kraft/ 20% CTMP
(3) 60% Kraft/ 40% CTMP
(4) 40% Kraft/ 60% CTMP
(5) 20% Kraft/ 80% CTMP
(6) 100% CTMP

Purchased Canadian spruce kraft and aspen CTMP will be used. The pilot plant papermachine will be run under alkaline conditions. Precipitated calcium carbonate will be used to fill the sheet approximately 12-15%. Cationic starch, AKD size and an anionic retention aid will be used to simulate an industrial application.

PHASE II:

Once the rotogravure stock is made it must be supercalendered. Phase II consists of supercalendering the paper on the pilot plant supercalender, also in Western Michigan University's pilot plant facility. Each of the furnishes will be supercalendered at constant speed, temperature, pressure and the same number of nips.

PHASE III:

Phase III consists of running a pilot plant rotogravure printing trial on the supercalendered paper. The printing trial will be run on the Cerutti rotogravure press in Welborn Hall, Western Michigan University Paper and Printing Department, Kalamazoo, Michigan.

Only one station of the four color rotogravure press will be used to print one color, preferably blue or red for good contrast. Water based ink will be used because of its environmental superiority over solvent based inks.

RAW MATERIALS

Fiber Furnish:

Dryden softwood Canadian spruce kraft pulp was chosen to constitute the kraft portion of the furnish. The pulp was shipped in dry lap form and refined on site. Softwood pulp was selected for its strength contribution at low addition levels, to ensure runnability through the pilot plant supercalender and the rotogravure printing press.

Tembec aspen CTMP was donated to be used as the remaining portion of the fiber furnish. The CTMP pulp was shipped to Western as a flash dried block. The pulp had a bleached brightness of 87% and a freeness of approximately 250 CSF. The aspen species was selected because it is the most common source for chemithermomechanical pulps on the market today.

Wet End Additives:

Pfizer high opacity precipitated calcium carbonate (PCC) was chosen because it was on stock in the paper pilot plant.

StaLok 400 cationic starch was chosen to be used as the wet end starch because of its high success rate in retaining sizing agents in alkaline papermaking systems. StaLok 400 is commonly used within alkaline papermills in the paper industry therefore, it simulates an industrial application.

An alkyl ketene dimer (AKD) sizing agent was chosen to be used with the cationic starch. Hercon 70 AKD size was used because it could be easily dispersed in water requiring no emulsification. Hercon 70 is recommended by Hercules for use in alkaline papermaking systems.

Because of the high filler loadings that are going to be attempted, an anionic retention aid was selected. The anionic retention aid is needed to retain the PCC and AKD. A representative of Hercules recommended using Retn 523P, a medium molecular weight, high charge density polymer.

EXPERIMENTAL PROCEDURES

Furnish Preparation

The Kraft and CTMP pulps were refined separately and each placed into separate blend chests. The Kraft pulp was beat in the pilot plant beater and refined to a freeness of 375 CSF in the pilot plant disk refiner. After refining, 20% PCC was added to the beater and allowed to mix. After thoroughly mixing the pulp and PCC were pumped into one of the blend chests.

The CTMP was shipped at a freeness of approximately 250 CSF so no refining was required. However because the pulp was flash dried it was in the form of a solid block. The easiest way to break up this block of pulp was to put it into the pilot plant hydropulper. After dispersing the pulp, 20% PCC was added and allowed to mix thoroughly. The pulp and PCC mixture was then pumped over into another blend chest.

For each of the six required furnishes, the proper ratio of Kraft to CTMP was pumped from each of the blend chests into the machine chest. For example, for the 80% Kraft/ 20% CTMP furnish, 80 pounds of the Kraft pulp and 20 pounds of the CTMP were pumped into the machine chest. Because 20% PCC was added to each of the pulps before going into the blend chests, the filler loading in the machine chest remains constant at twenty percent. The freeness of each of the combined pulp mixtures was measured and is recorded in Table 7 below.

Table 7: Combined Pulp Freeness

Condition	Furnish	Combined Freeness
1	100 % Kraft	422 ml/min
2	80% Kraft/ 20% CTMP	408 ml/min
3	60% Kraft/ 40% CTMP	364 ml/min
4	40% Kraft/ 60% CTMP	368 ml/min
5	20% Kraft/ 80% CTMP	373 ml/min
6	100% CTMP	342 ml/min

Wet End Additives

Before the pilot plant machine run, all the wet end additives had to be diluted so that they could be metered to the papermachine by the parastolic pumps in the pilot plant. The pumps are rated for flow rates of 100-700 ml/min. Table 8 illustrates the concentration as shipped, the concentration going into the papermachine and the flow rate going to the papermachine for each of the wet end additives.

Table 8: Additive Concentration Data

Additive	Arriving Concentration	Papermachine Concentration	Flow Rate
StaLok 400	89.1 % Solids	3.0 % Solids	525 ml/min
Hercon 70	12.5 % Solids	1.0 % Solids	105 ml/min
Retn 523P ml/min	98.0 % Solids	0.15 % Solids	175

The StaLok 400 starch was cooked in the pilot plant batch starch cook. The cooker applies steam to the starch slurry and cooks the starch at approximately 225 degrees Fahrenheit.

The Hercon 70 AKD size was simply diluted and thoroughly mixed the morning of the machine run.

Due to the high molecular weight of the Retn 523P, the manufacturer suggested diluting it very slowly and allowing it to mix thoroughly. To prevent agglomeration, the polymer was added slowly to thirty gallons of water and allowed to mix under a lightening mixer for about ninety minutes.

Once all the wet end additives were properly made down, lines were run from the barrels of chemicals to the proper addition point on the papermachine. The parastolic pumps in the pilot plant were used for metering the chemicals. Table 9 illustrates the addition point and rate for each of the wet end chemicals.

Table 9: Wet End Additive Data

Additive	Addition Point	Addition Rate
PCC-HO	Machine Chest	20 %
StaLok 400	1st Mix Box	20 #/Ton
Hercon 70	2nd Mix Box	2 #/Ton
Retn 523P	Before Fan Pump	0.5 #/Ton

Papermachine Run:

In the papermachine run, six different fiber furnishes will be made while maintaining all machine conditions and additive flow rates constant. The six conditions and their respective numbers are listed below, for the remainder of this report each of the conditions will be referred to by their respective number (1-6).

(1) 100% Kraft
(2) 80% Kraft/ 20% CTMP
(3) 60% Kraft/ 40% CTMP
(4) 40% Kraft/ 60% CTMP
(5) 20% Kraft/ 80% CTMP
(6) 100% CTMP

In order to produce enough paper to supercalender and run a printing trial, 2000 feet of each condition needed to be made. An excessive amount (5000 feet) of the 100% Kraft condition was made to allow for proper alignment of the gravure press during the printing trial.

For each fiber furnish the proper ratio of kraft and CTMP was pumped into the machine chest, to produce the desired amount of paper. The pulp in the machine chest was allowed to run out before the next ratio of pulp furnishes was pumped over to the machine chest. The paper from each condition was collected onto separate rolls and set aside for supercalendering.

During the paper machine run, papermachine conditions were monitored and recorded. These conditions are listed in Table 10. The pilot plant papermachine was run with the dandy roll down and through three nips on the machine calender. The size press was not used.

Supercalendering:

Each of the six conditions were made on six different rolls of paper. All of the rolls of paper were supercalendered under constant conditions, beginning with the 100% Kraft. Initially the supercalender variables were adjusted with the 100% Kraft paper, so a few breaks were encountered. After the conditions were stabilized only one break was experienced, it was during the 100% CTMP furnish condition.

The paper was supercalendered through five nips of the supercalender at 350 fpm. The rolls of the supercalender were heated to 170 degrees Celsius and had an applied linear loading on of 1700 pli.

Table 10: Machine Conditions

Conditions	1	2	3	4	5	6
Stock Valve Opening (%)	2.8	2.8	2.8	2.8	2.8	2.8
Headbox Flow (gpm)	13.2	12.6	14.1	15.2	15.7	16.8
Headbox pH	7.4	7.3	7.3	7.3	7.3	7.5
1st Press (psi) F	41	40	40	40	40	40
B	40	41	40	40	40	40
2nd Press (psi) F	35	34	33	34	33	33
B	42	42	41	40	40	40
1st Dryer (F)	160	160	160	160	160	160
2nd Dryer (F)	190	192	192	192	192	192
1st Dryer Section (F)	215	215	218	220	220	220
2nd Dryer Section (F)	155	155	155	155	155	155
Wire Speed (fpm)	101	101	101	101	100	100
Vaccum Box (in Hg)	4/6	4/6	4/6	4/5	4/5	5/6

After supercalendering each of the six rolls, they were taken to Redmond's Paper Merchants for rewinding. All of the rolls were rewound onto one roll, so that each of the samples could be printed without having to rethread the printing press. The samples were rewound at approximately 700 fpm, with the 100% CTMP at the core and the 100% Kraft on the outside. Only one break was experienced during rewinding, it was on the 100% CTMP condition.

Printing Trial:

The paper was printed on the pilot plant Cerutti gravure press in Welborn Hall. One color water based ink was printed at 300 fpm. Initially some problems were experienced with streaks, so the blade was changed. After stabilizing all the press conditions, each of the six different furnish samples were printed.

Paper Evaluation:

After production and printing of the paper was complete samples were tested and analyzed to determine the effects of the addition of CTMP to the fiber furnish. Samples of each condition were selected randomly to minimize variability in the sampling technique.

Three types of testing were done: physical, optical and printing quality. Machine direction tensile and cross machine direction internal tear were tested to determine the physical strength of the sheets. These tests were chosen because they most closely simulate the stresses applied in a printing press. Brightness, gloss and opacity were measured to compare the optical properties of the samples to an accepted specification for SCB grade papers. Finally print quality was approximated by measuring Sheffield Smoothness and Parker Print Surf; print quality was measured by performing image analysis on printed samples of each condition.

All testing was done in accordance to the respective TAPPI Standards, see Table 11. The testing data for each of the tests performed can be found in Appendix 1.

Table 11: Evaluated Paper Properties

Property	TAPPI Standard
Ash (%)	T413 om-80
Basis Weight (g/m2)	T410 om-83
Brightness (%)	T452 om-82
Caliper (1/1000 in)	T411 om-82
Gloss (%)	T480 om-80
Opacity (%)	T425 om-81
Parker Print Surf (at kgf/cm2)	---
Smoothness (Sheffield Units)	T526 om-83
Tear Index (mNm2/g)	T414 om-82
Tensile Index (Nm/g)	T404 om-82

RESULTS AND DISCUSSION

Due to the lack of pilot plant time and cost of raw materials each of the six conditions was only run once. Therefor, a statistical analysis was not made on the following results. For further statistical analysis the results of this project should be duplicated and compared.

Freeness:

The softwood kraft pulp was refined to approximately 375 CSF and the CTMP was used as received about 250 CSF. As Table 7 illustrated, the combined pulp freeness varied between 422 and 342 CSF. Although this freeness variation is significant it was unavoidable, because refining the softwood pulp below 375 CSF would have been destructive to the fibers. However conditions 2-5 have somewhat similar freeness results.

When the 375 CSF kraft pulp and the 250 CSF CTMP were combined, larger freeness variations were expected. The freeness values of the six conditions were much more consistent, the addition of the PCC to the machine chest may have increased the freeness results.

Machine Conditions:

During the papermachine run, it was attempted to keep all the machine conditions and additive addition rates constant. Table 4 lists the machine conditions that were monitored during the trials. As the data illustrates, no significant changes were made to the machine conditions during the trial.

Also during the machine run the additive flow rates were monitored to be sure that the correct amounts of chemicals were being metered into the papermachine system.

Retention:

As the trial progressed it became evident that increasing the amount of CTMP in the furnish reduced the retention of the system. At the beginning of the trial, when the 100% kraft furnish was made, the whitewater samples were essentially clear. Adding CTMP to the furnish caused the whitewater to become cloudy. The first pass retention values and ash results can be found in Table 12.

These results were expected because the long softwood fibers tend to form an entangled mat that traps the filler and sizing particles as they are draining through the wire. Replacing these long fibers with short hardwood fibers causes some of the filler and sizing particles to pass through with the whitewater, thus reducing retention. Although sizing values were not of concern in this project, it was observed that the HST sizing values also fell off with increasing addition of CTMP.

Table 12: Retention Results

	1	2	3	4	5	6
HB Cons (%)	0.16	0.19	0.4	0.57	0.51	0.46
Tray Cons (%)	0.0	0.01	0.07	0.15	0.12	0.14
1st Pass (%)	100	94.7	82.5	73.7	76.5	69.6
% Sheet Ash	14.4	13	13.4	12.8	12.2	12.0

As Table 12 and Figure 4 show the sheet ash level fell from 14.4% in the 100% kraft sheet to 12.0% in the 100% CTMP sheet. This change of 2.4% sheet ash will affect sheet strength and must be kept in mind when analyzing strength results.

Comparison of Furnishes:

For good machine runnability it was decided to make 58 g/sq m (35 #/3000 sq ft) the grammage target for all of the furnish conditions. Figure 5 graphically represents the grammage results for each of the six conditions. From these results it can be noted that except for the first condition, the grammage values were within the target range. Because these values were within the target range, the samples from each of the conditions can be compared for further results.

Figure 4:

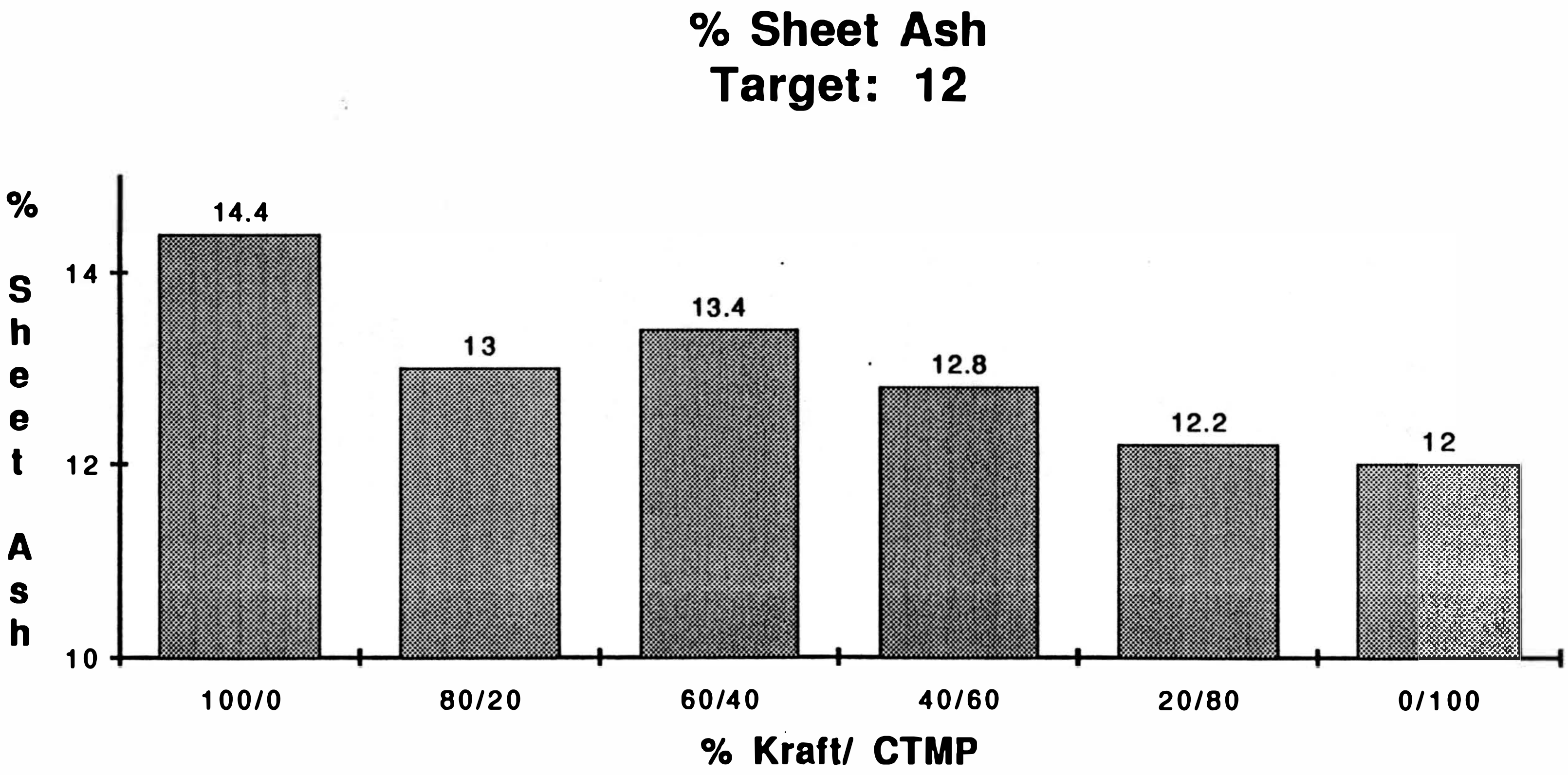


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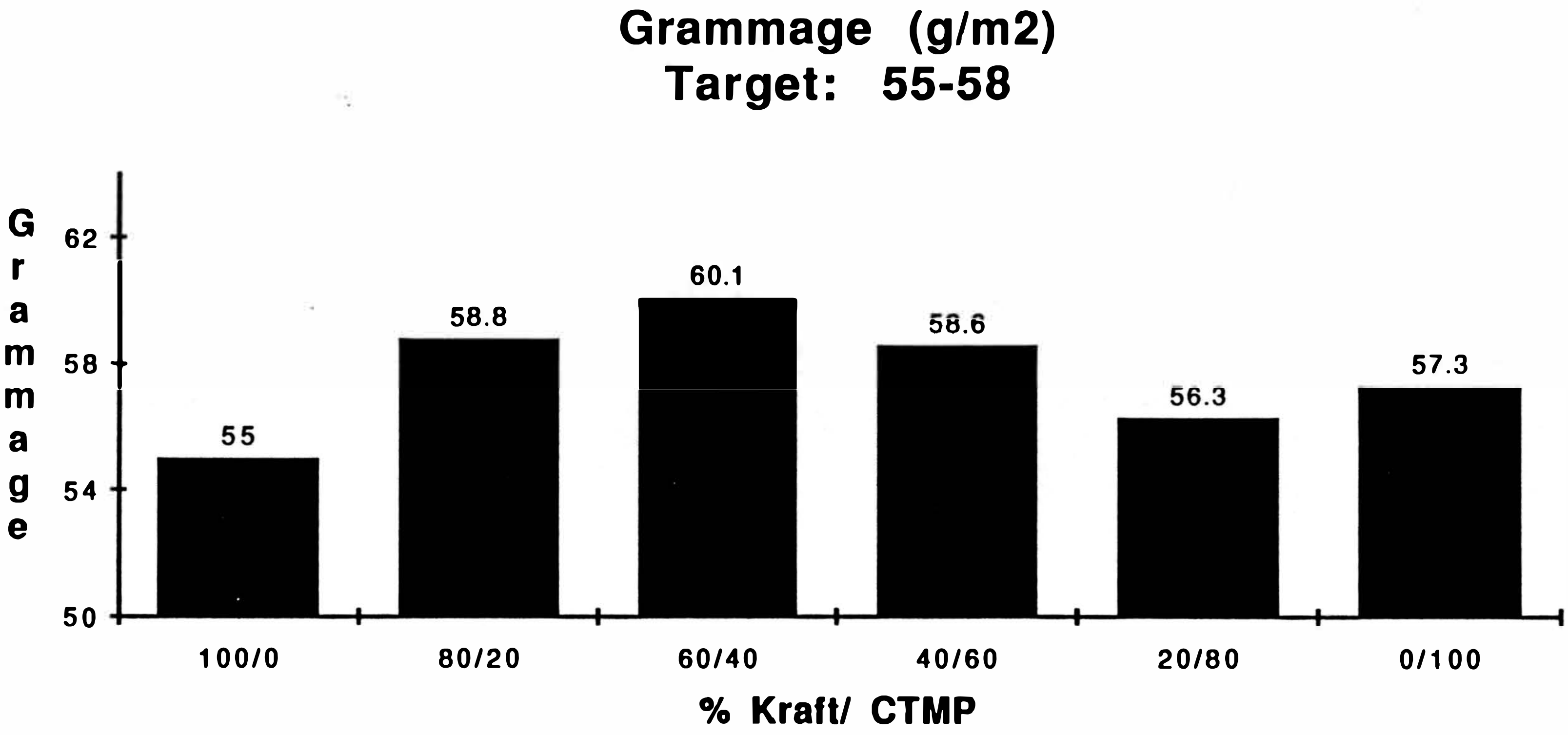
Figure 5:


Grammage (g/m2)
Target: 55-58
Grammage
62
58
54
50
55
58.8
60.1
58.6
56.3
57.3
100/0
80/20
60/40
40/60
20/80
0/100
% Kraft/ CTMP

Strength Properties:

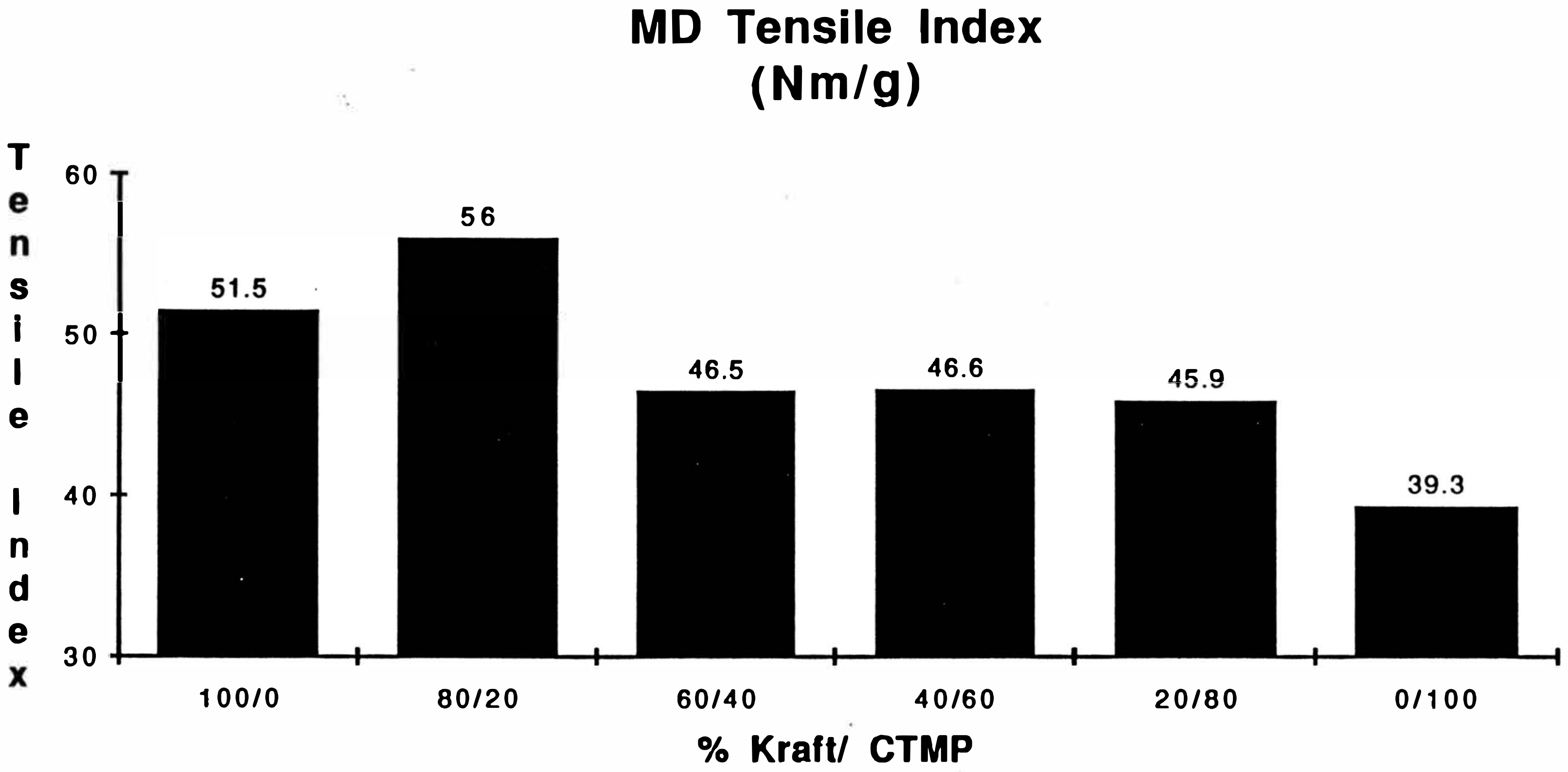
Two strength properties were chosen to evaluate the paper strength: MD Tensile Index and CD Tear Index. These tests were chosen because the approximate the stresses and strains that the paper web would be subjected to in a high speed gravure printing press.

As Table 1 shows, there is no strength requirement for SCA or SCB grades. The primary requirement for supercalendered paper grades is that it have good supercalender and printing press runnability. The printer does not measure the web strength in terms of a physical test result, he looks at the number of web breaks per roll of paper.

When considering the number of web breaks that occurred during the printing trial, the results indicate that all of the samples ran through the press without breaking. The fact that no web breaks were encountered on the printing press illustrate that the paper had sufficient web strength to ensure press runnability.

Machine direction (MD) tensile results approximate the tension strains that are put on the web during the printing process. The results of the MD tensile testing are shown in Figure 6. From the graph it can be seen that at high addition levels of the kraft pulp, high tensile indexes were achieved. The increase in tensile resulting from replacing 20% kraft with 20% CTMP can most probably

Figure 6:



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be attributed to an increase in bonding due to the higher surface area of the CTMP fibers.

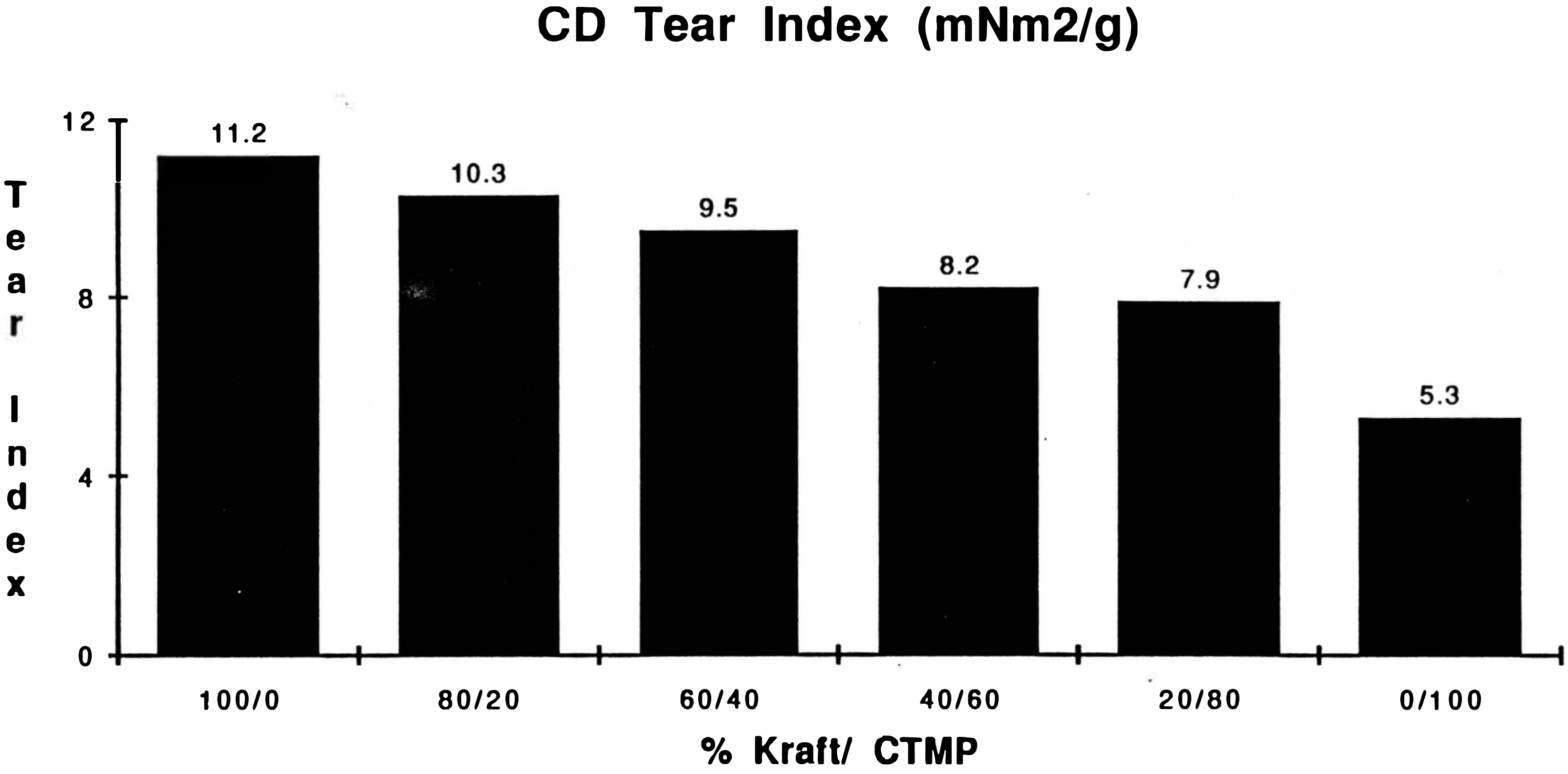
The graph also indicates no significant difference in replacing 40 to 80% of the kraft in the furnish. This indicates that the additional kraft fibers in the furnish are not contributing to the tensile strength of the sheet. However, removing all of the kraft in the furnish creates a dramatic drop in tensile strength. These results indicate that a small portion of kraft should remain in the fiber furnish, to ensure supercalender and press runnability.

The results of the cross directional (CD) internal tearing resistance approximate what would happen if a hole or cut in the web occurred during the printing process. These values illustrate the amount of resistance the sheet would have to increasing the size of the hole and causing a web break on the press.

Figure 7 diagrams the results of the CD Tear tests. These results illustrate the more expected strength reduction with decreasing amounts of kraft in the fiber furnish. However again, it can be observed that in the 40% and 20% kraft furnishes a dramatic strength difference can be noted. Also, as in the tensile results when the kraft is complete removed from the fiber furnish the strength drops off significantly.

The results from both the MD Tensile and CD Tear

Figure 7:



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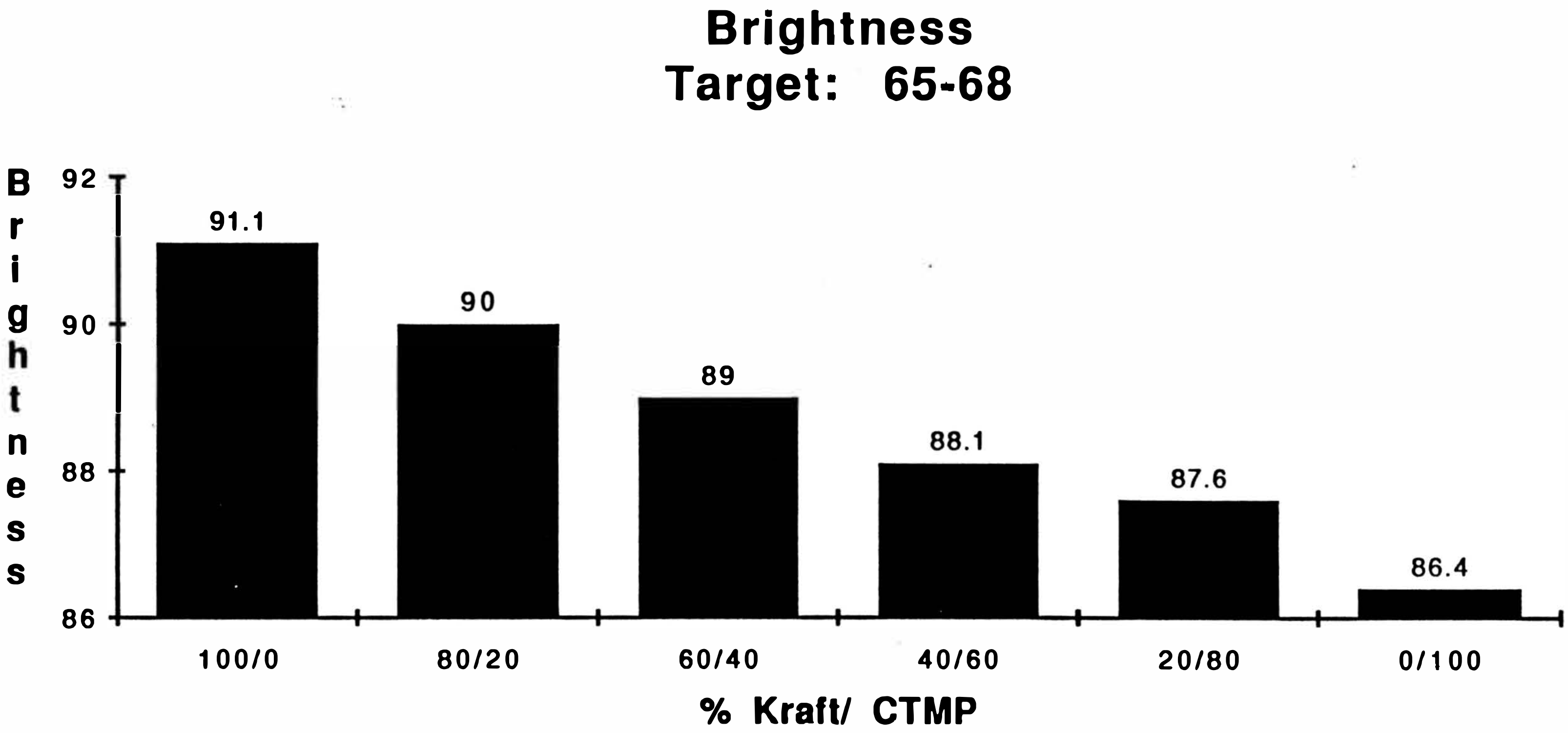
illustrate that below approximately 60% kraft, no dramatic strength advantages can be noted from additional kraft fibers in the furnish. However completely removing the kraft portion of the furnish did result in a dramatic effect on the web strength. It would be interesting to see what the strength results for a 10% kraft and 90% CTMP furnish would have been. However, from the results presented it appears that a small portion of kraft must remain in the fiber furnish to ensure good press runnability. Approximately 10-20% kraft should give an adequate amount of strength, the results presented illustrate that increasing the kraft content above 20% would not significantly affect strength.

Optical Properties:

Table 1 suggests that three optical specifications must be met by supercalender grade papers. The three optical tests that were performed on the paper samples are: brightness, opacity and gloss. During this trial the quality data specifications shown in table 1 were used as targets points.

The brightness target for supercalendered grades is 65-68%. The results of the brightness testing graphically represented in Figure 8 show that all of the samples exceeded this target. The paper samples in this trial had such high brightness results because bleached kraft and bleached CTMP were used. Due to the unavailability of

Figure 8:



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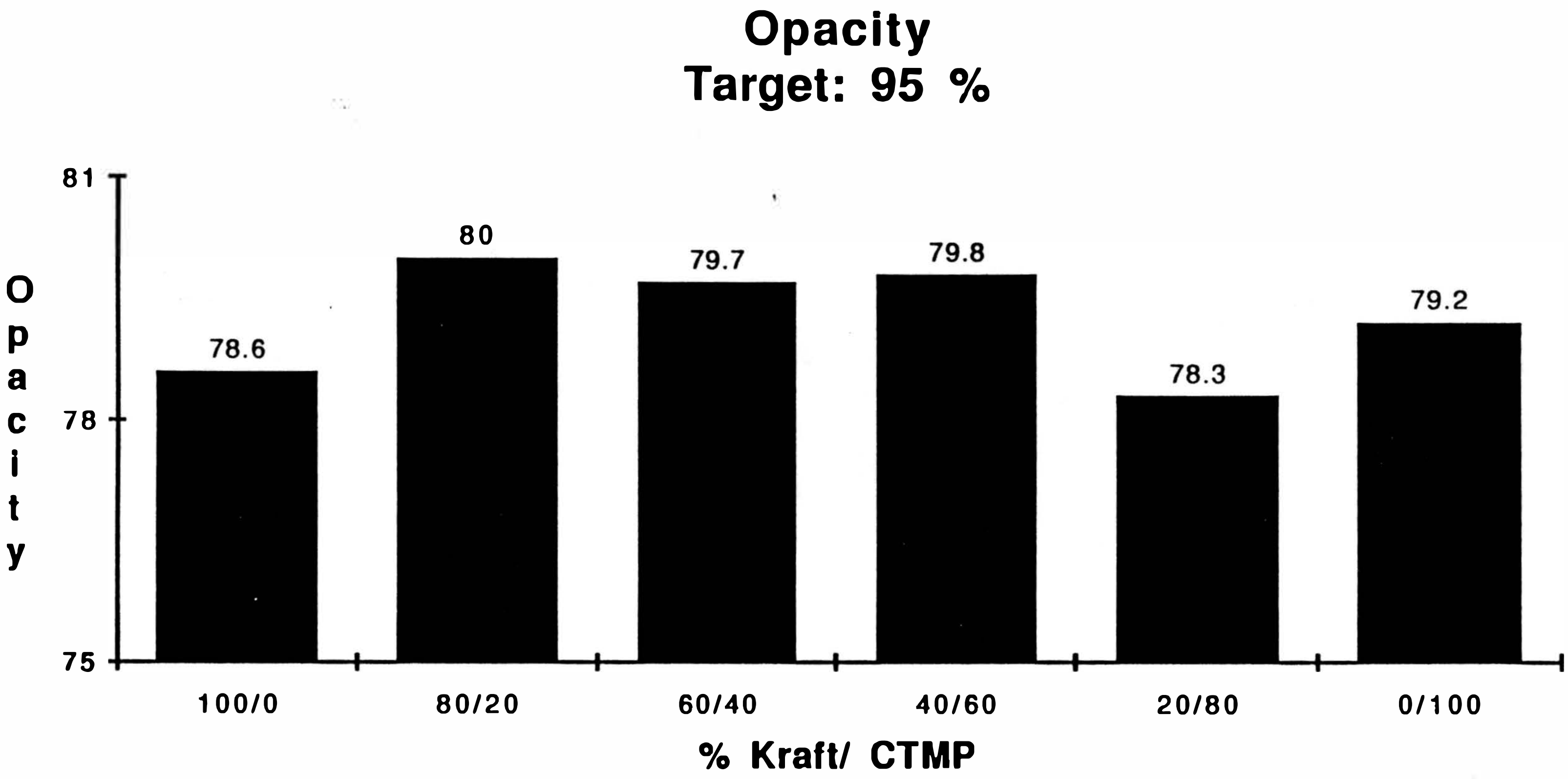
unbleached CTMP, bleached raw materials were used. In an industrial production of SCB grades, unbleached pulps would be more economical to use.

The brightness test results were taken approximately one week after supercalendering to allow for any natural reversion that would occur in the CTMP. The graph shows an incremental brightness decrease with increasing amounts of CTMP. This can be attributed to the higher brightness of the kraft over the CTMP and the natural tendency for the CTMP to revert with time. Because SCB grade papers are used predominately for advertisements, cheaper magazines and newspaper inserts, the brightness reversion that is experienced with mechanical pulps are not significant, they will not be around long enough to revert.

A 95% opacity target was attempted during this trial. As the opacity results in Figure 9 describe, none of the samples even came close. Several variables could be optimized in further studies to improve opacity results. Increasing the amount of filler will improve the sheet opacity, also varying supercalender conditions can aid in improving opacity. Most industrial supercalenders have steam or water showers on the supercalender to increase the sheet moisture going into the supercalender nips. The pilot plant supercalender is not equipped with these showers so the paper had to be supercalendered at

Figure 9:



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the moisture it left the reel at.

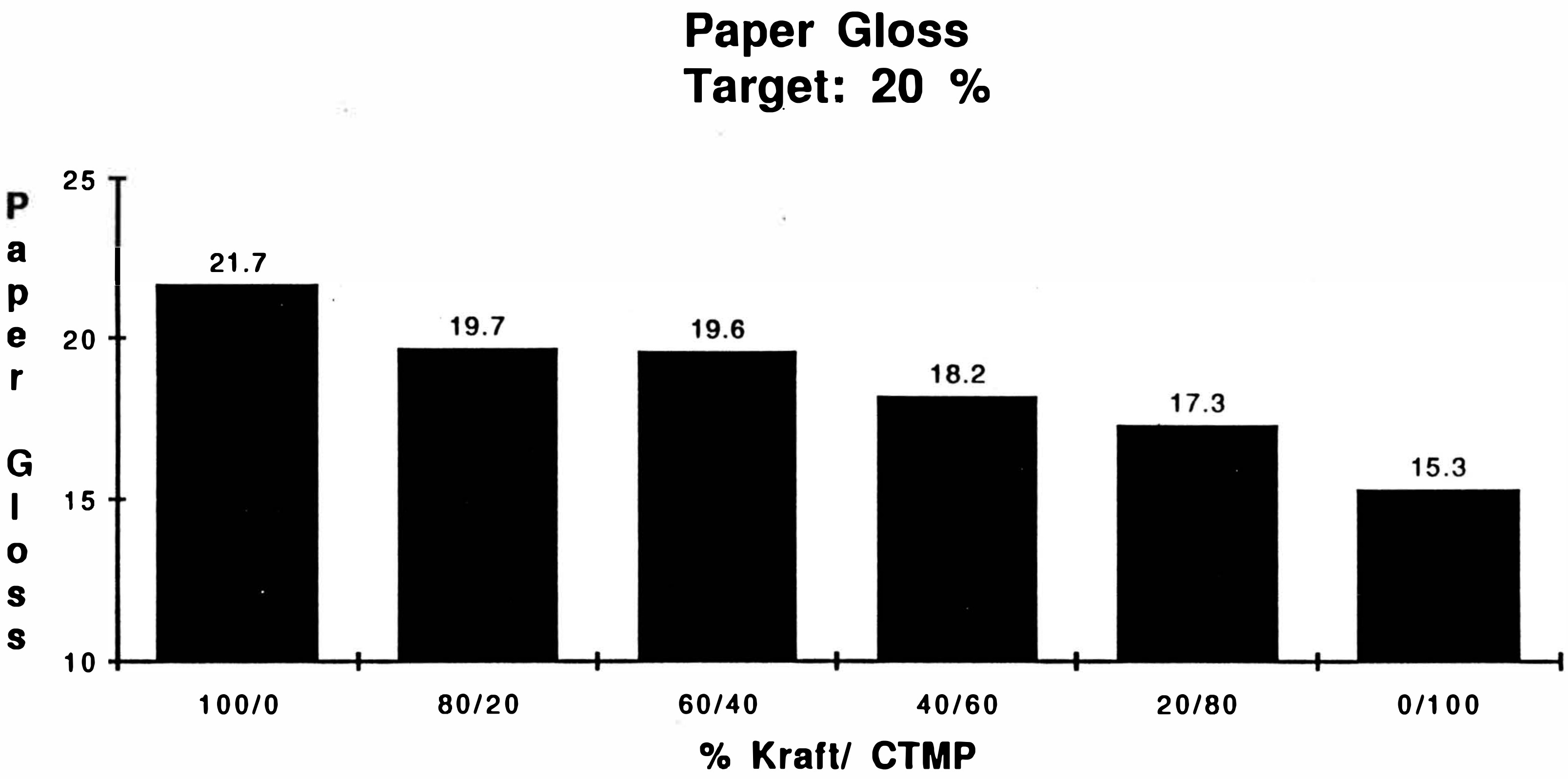
The opacity results did not vary dramatically from one condition to the next, in fact all the results were within two percentage points of each other. Therefore it can be concluded that the furnish had no significant effect on the sheet opacity.

The paper gloss of each of the six samples was tested and recorded in Figure 10. A target of 20% gloss was aimed for. The graph indicates that the furnishes containing higher amounts of kraft had higher gloss values. This can most probably be explained be the decreasing amount of sheet ash with increasing amounts of CTMP in the furnish.

Variation in the supercalendering conditions and the addition of a water or steam box would improve gloss measurements. Although the target gloss values were not achieved the gloss results were good. With further variations of the supercalendering conditions the gloss target should be easily achievable.

The results of the optical tests indicate that the paper samples produced could be used as SCB grade paper. Further optimization of supercalendering variables should bring the opacity and gloss values into specification.

Figure 10:



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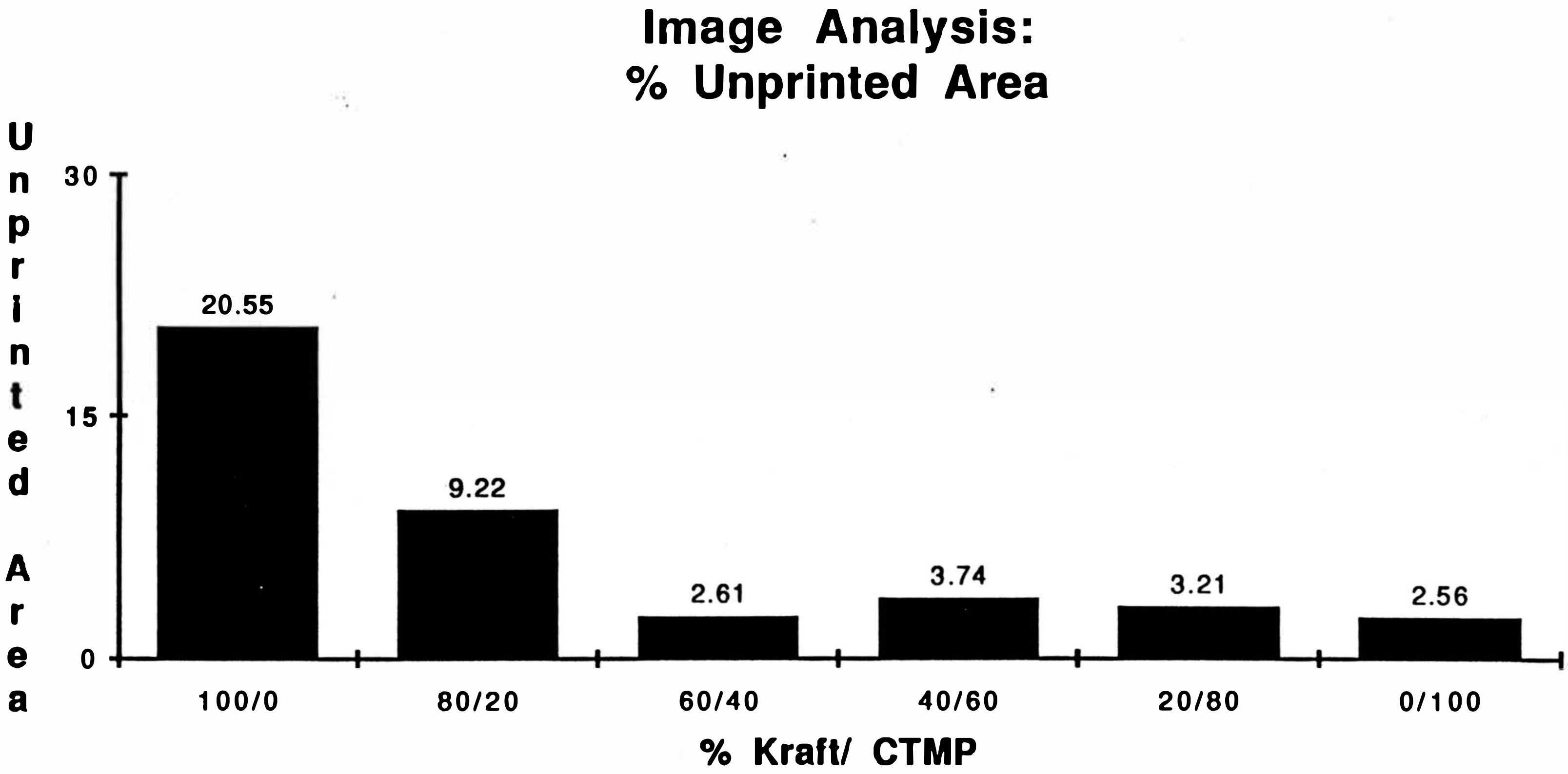
Printing Quality:

There are several paper tests that approximate printing quality. However, there is no better determination of print quality than to actually print the paper samples. Since the equipment was available on campus, a printing trial on the Cerutti gravure press in Welborn Hall was performed. The results of this printing trial and the paper tests results of the unprinted sheets were used to determine the overall print quality of the samples.

Samples from the printing trial for each furnish conditions were evaluated by the image analyzer. Typically the image analyzer uses variations in light reflectance to determine the amount of contamination (dirt, stickies, etc...) in a paper sample. The analyzer determines this by finding the dark spots in the white paper. By reversing the polarity of the analyzer it was used to determine the % unprinted area in a uniform solid sample from each condition. Reversing the polarity caused the analyzer to pick out the white unprinted areas from the dark printed area.

The results of the image analyzer comparison are shown in Figure 11. This graph shows that increasing the amount of CTMP in the furnish significantly reduced the percentage unprinted area. Except for the point containing 60% kraft, the percent unprinted area reduced

Figure 11:



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incremental by increasing the amount of CTMP in the fiber furnish.

Sheffield Smoothness and Parker Print Surf tests were also performed on unprinted paper samples to estimate print quality.

The results of the Sheffield Smoothness testing are graphically represented in Figure 12. The data illustrates that increasing the amount of CTMP in the furnish increased the sheet smoothness. Although the target value of 60 Sheffield units was not achieved, further optimization of supercalendering conditions could reduce the smoothness values.

Parker Print Surf was done at a clamping force of 10 kgf/sq cm with a hard backing plate. The results of these tests are graphically shown in Figure 13. Increasing the amount of CTMP in the furnish increased the Parker Print Surf results, thus indicating that the sheet smoothness was improved.

The results of both the analysis of the printed material and the unprinted material indicate that the incorporation of CTMP into the pulp furnish increases the overall printability. From figures 11-13 it can be concluded that the sheets containing higher amounts of CTMP have better printability than the sheets containing high amounts of kraft.

Figure 12:

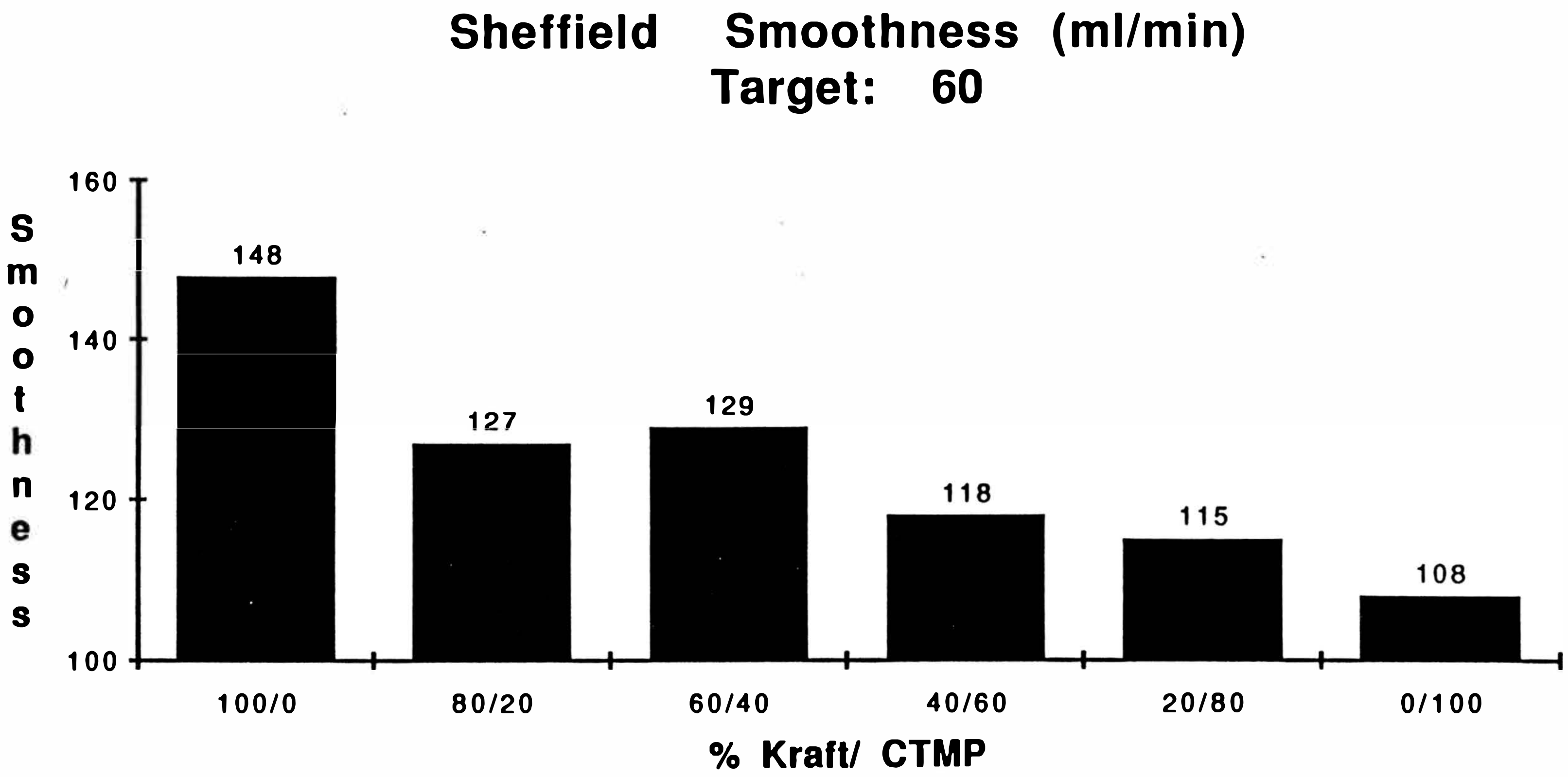

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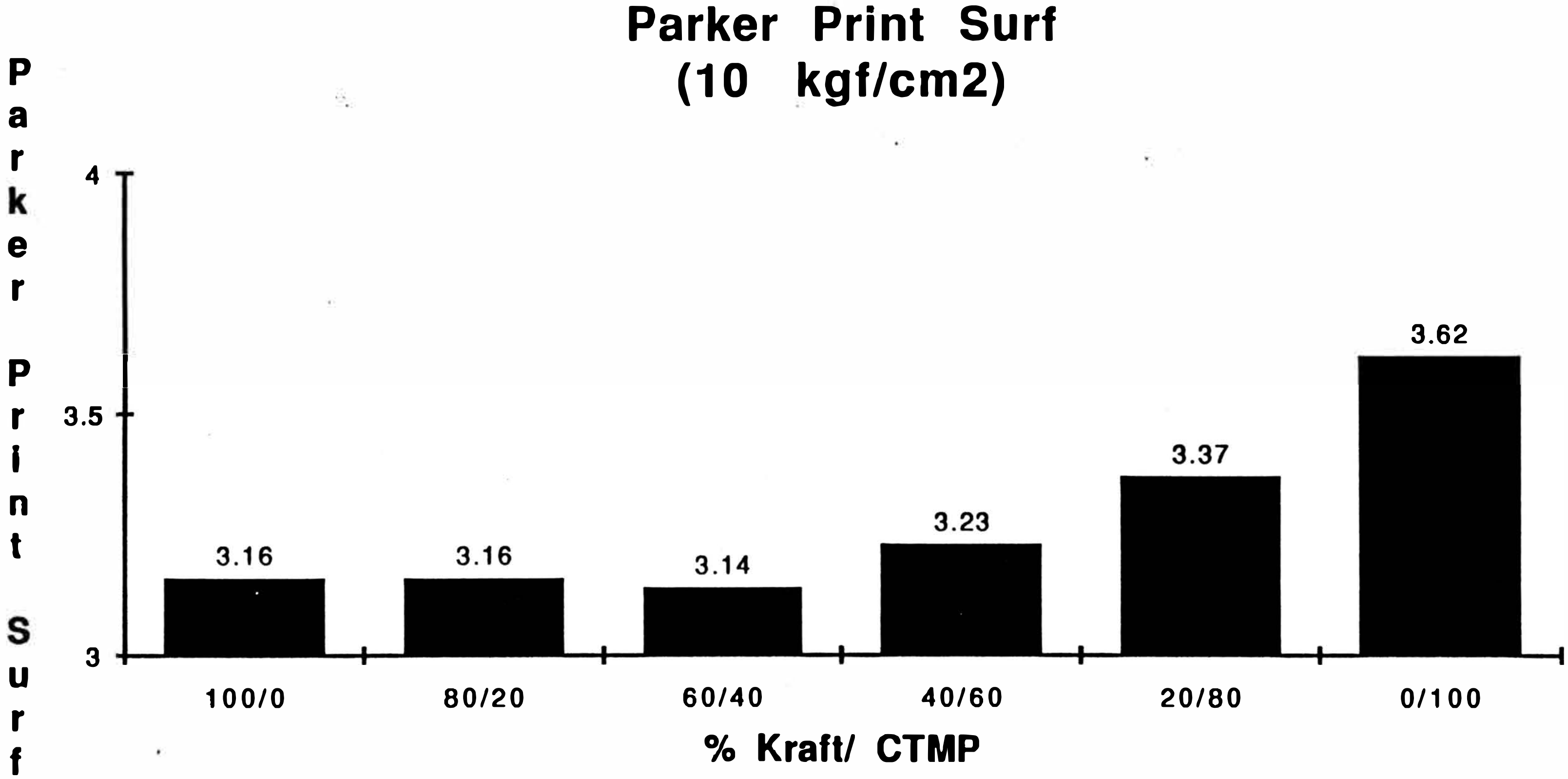
Figure 13:



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CONCLUSIONS

In conclusion the results of this study indicate the potential for use of chemithermomechanical pulp in the production of supercalendered grade B papers. The conclusions from this thesis can be summarized as follows:

1. Web strength of sheets containing high percentages of CTMP had sufficient strength to ensure printing press runnability.

2. Decreasing the amount of kraft in the fiber furnish from 60% to 20% had no significant effect on sheet strength properties.

3. Replacing all the kraft fibers in the furnish produced a dramatic decrease in sheet strength. Thus, illustrating that a small amount of kraft should stay in the furnish to ensure runnability.

4. Increasing the amount of CTMP in the fiber furnish significantly reduced the percentage unprinted area of a printing sample.

5. Both Sheffield Smoothness and Parker Print Surf were improved with the addition of CTMP into the fiber furnish.

6. The results of the printing evaluations showed that the addition of the CTMP into the sheet furnish improved overall print quality.

To summarize, the results of this thesis indicate that CTMP is a posible alternative for the production of supercalendered grade B papers. Strength properties, optical properties and overall printing performance for the CTMP containing sheets were satisfactory. The strength results indicate that some kraft fiber, approximately 10% should remain in the furnish to ensure runnability. However the results show that further increases in the kraft content will not significantly improve strength.

Incorporating CTMP into the furnish for supercalendered grade B papers is economical. Replacing the mechanical portion of the fiber furnish with CTMP would allow even more of the chemical portion to also be replaced because CTMP has higher strength than other mechanical pulps. Also CTMP also has higher yields than kraft chemical pulps.

In December 1990 CTMP was selling on the open market for about $480-530/ton while kraft pulps were going for $690-730/ton. From these figures it can easily be seen that reducing the expensive kraft fraction of the fiber furnish and replacing it with the cheaper CTMP adds up to considerable savings for the paper mill.

SUGGESTIONS FOR FURTHER STUDY

1. In order to statistically verify the results of this thesis, the pilot plant work should be duplicated and compared to the results of this study.

2. Further work should be investigated to optimize the pilot plant supercalendering conditions for supercalendered grade B papers.

3. The addition of CTMP into the fiber furnish produced an apparent reduction in filler and AKD retention. Further investigations should be done to study the effects of CTMP on retention.

4. The results of this work indicated that reducing the kraft furnish content from 20% to 0% dramatically affected sheet strength. Further optimization work should be done to determine the strength affects from 20% to 0%. How much kraft is required in the furnish before the strength dramatically falls off?

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APPENDIX A: SUPERCALENDERED PAPER TEST RESULTS

BASIS WEIGHT (#/3000 sq ft) and GRAMMAGE (g/ sq m)

Grams per 1.5 sq ft

	1	2	3	4	5	6
	7.67	8.22	8.31	8.01	8.11	8.1
	7.76	8.29	8.44	8.2	7.88	8.09
	7.75	8.21	8.7	8.17	7.85	8.1
	7.89	8.21	8.72	8.23	7.91	8.1
	7.74	8.16	8.44	8.17	7.76	8.09
	7.73	8.33	8.23	8.21	7.77	8.01
	7.29	8.13	8.21	8.18	7.8	7.89
	7.64	8.11	8.16	8.03	7.82	7.85
	7.38	8.1	8.25	8.19	7.81	7.79
	7.8	8.25	8.2	8.22	7.83	7.85
Average	7.67	8.2	8.37	8.16	7.85	7.99
Std Dev	0.18	0.07	0.19	0.07	0.1	0.12
#/3000 sq ft	33.82	36.16	36.9	36	34.61	35.23
g/sq m	55.04	58.84	60.06	58.56	56.33	57.34

BRIGHTNESS (%)

	1	2	3	4	5	6
	91.1	89.97	88.79	88.33	87.49	86.6
	90.23	90.11	89.29	88.1	87.83	86
	90.73	89.7	88.07	87.98	87.61	86.2
	91.2	90.14	89.13	88.51	87.65	86.4
	90.95	89.94	88.77	87.96	87.3	86.5
	90.92	90.11	89.15	87.95	87.67	86.4
	91.03	90.04	89.2	88.28	87.71	86.2
	90.91	90.09	89.05	88.22	87.14	86.5
	91.23	89.73	89.01	88.53	87.35	86.5
	91.04	89.93	88.83	88.08	87.65	86.3
	91.34	90.16	88.97	88.47	87.67	86.5
	91.51	90.61	89.05	87.96	87.96	86.3
	91.79	89.88	89.2	88.28	87.37	86.7
	91.62	90.04	89.35	88.44	87.8	86.9
	91.07	90.13	89.22	86.48	87.44	86.6
Average	91.11	90.04	89.01	88.1	87.58	86.44
Std. Dev	0.36	0.21	0.3	0.47	0.21	0.21

CALIPER (1/1000 inch)

	1	2	3	4	5	6
	7.3	7.5	7.5	7.9	7.7	8.5
	7.4	7.6	7.4	7.9	7.7	8.4
	7.45	7.4	7.4	7.8	8	8.5
	7.45	7.4	7.4	7.9	7.8	8.5
	7.2	7.4	7.5	7.7	7.6	8.4
	7.4	7.6	7.2	7.9	7.7	8.4
	7.1	7.6	7.5	7.9	7.6	8.4
	7.1	7.3	7.5	7.7	7.7	8.4
	7.4	7.4	7.4	7.6	7.7	8.3
	7.2	7.2	7.4	7.6	7.6	8.4
	7.4	7.6	7.5	8	8.1	8.3
	7.2	7.5	7.5	8	7.6	8.3
	7	7.6	7.2	8	7.6	8.2
	7.4	7.4	7.5	7.7	7.5	8.4
	7.1	7.4	7.4	7.9	7.9	8.6
Average	7.27	7.46	7.42	7.83	7.72	8.4
Std Dev	0.15	0.12	0.1	0.13	0.16	0.1

CD TEAR (mN sq m/g)

	1	2	3	4	5	6
	19.5	19.5	18.5	15	18	11
	19	19	18	16	18.5	10.5
	18	18.5	18	14.5	17.5	10.5
	19.5	18.5	17.5	15.5	16	12
	20	20	18.5	16	16.5	11.5
	19.5	19.5	19.5	16	16	11
	20.5	20.5	18	15.5	18	13.5
	20	19	18.5	14.5	17	11.5
	22	19.5	17.5	14	16.5	13
	19	19	18	15.5	16.5	12
Average	19.7	19.3	18.2	15.25	17.05	11.65
Std Dev	1	0.6	0.56	0.68	0.85	0.95
Tear Index	11.23	10.3	9.51	8.2	7.94	5.34

GLOSS 75 DEGREE (%)

	1	2	3	4	5	6
	23	19.7	22.2	16.4	16.2	15.3
	20.7	18.7	20.2	16.8	18.6	17.1
	21.7	18.9	19.4	18.5	19.9	16.8
	23	20	19.5	17.5	16.4	15.8
	19.6	19.9	19.7	16.9	17.2	15.1
	23.7	19.4	21.4	20.3	19.1	15.3
	19.7	21.5	19	18.8	17	14.6
	24	20.3	18.5	16.7	15.7	14.6
	23	20.1	17.7	18.8	16.2	14.8
	19.8	19.5	17.6	17	16.5	15.1
	18.5	19.2	18.8	18.1	19	15.4
	20.2	18.6	18	20.5	15.8	15.1
	21.8	18.4	19	20.1	17	14.8
	22.9	21.3	22.9	16.4	16.8	15.1
	23.5	20.5	19.8	20.2	17.4	13.8
Average	21.67	19.73	19.58	18.2	17.25	15.25
Std Dev	1.72	0.89	1.51	1.47	1.26	0.8

MD TENSILE (N m/g)

	1	2	3	4	5	6
	7.45	8.25	7.2	7.1	6.95	6.1
	7.5	9.1	7.15	6.45	6.2	5.15
	6.3	8.55	7.7	7.85	7.15	6.15
	6.6	7.55	8.15	7.2	6.35	5.7
	7.1	8.7	7	6.8	7.5	5.65
	7.4	7.9	8.35	6.75	6.45	5.35
	6.55	8.4	7.45	6.7	6.5	4.45
	6.6	8.45	6.95	6.8	6.45	5.4
	7	7.7	6.45	6.8	6.25	6.25
	8.3	8.35	7.1	7.15	6.55	5.4
	7.95	8.45	7.15	6.5	6.3	6.1
	7.65	9.05	6.2	6.8	6.25	6.25
	7.15	8.25	6.3	6.7	7.25	5.75
	7.35	8.95	6.6	7.85	6.65	6.6
	7.6	8.4	7.1	7	6.05	5.8
Average	7.23	8.4	7.12	6.96	6.59	5.74
Std Dev	0.54	0.44	0.59	0.4	0.41	0.52
Tensile Index	51.5	56	46.5	46.6	45.9	39.3

OPACITY (%)

	1	2	3	4	5	6
	79.4	79.8	80.1	78.9	79.2	79.9
	77.1	80.4	79	79.8	79.9	79.8
	79.3	79.1	78.4	80.2	78.2	77.8
	76.2	80.4	79.3	79.1	77.3	79.8
	78.1	81.1	80	80.5	77.9	79.5
	77.9	80.5	80.6	79.2	78.1	79.9
	78.5	80.3	79.8	79.6	77.7	78.3
	80.2	79.9	79.2	80.4	78.7	79.9
	79.9	79	80.1	79.8	77.7	79.1
	80.9	79.6	80.7	78.9	78.7	79.3
	79.6	80.4	80.1	80.4	77.3	78.6
	78.7	80.2	79.9	81.1	77.4	78.7
	79	79.2	78.9	79.5	78	78.2
	77.6	80	79.4	79	78.9	79
	76.7	80.1	80.3	80.2	79.9	80.5
Average	78.61	80	79.72	79.77	78.33	79.22
Std Dev	1.3	0.56	0.64	0.66	0.83	0.75

PARKER PRINT SURF (10kgf/sq cm)

	1	2	3	4	5	6
	3.2	3.25	3.05	3.2	3.35	3.65
	3.3	3.1	3.05	3.25	3.3	3.65
	3.1	3.15	3.1	3.3	3.45	3.55
	3.05	3.1	3.05	3.2	3.3	3.6
	3.25	3.15	3.05	3.1	3.2	3.5
	3	3.2	3.1	3.2	3.4	3.5
	3.1	3.3	3.15	3.35	3.4	3.65
	3.2	3.2	3.1	3.4	3.3	3.7
	3.3	3.25	3.1	3.25	3.35	3.8
	3.2	3.15	3	3.2	3.3	3.6
	3.2	3.35	3.1	3.3	3.4	3.5
	3.05	3	3.95	3.3	3.55	3.55
	3	3.1	3.1	3.15	3.35	3.75
	3.15	3.1	3.15	3.1	3.4	3.65
	3.3	3.05	3.05	3.1	3.5	3.6
Average	3.16	3.16	3.14	3.23	3.37	3.62
Std Dev	0.1	0.09	0.22	0.09	0.09	0.09

SMOOTHNESS (Sheffield Units)

	1	2	3	4	5	6
	130	135	130	110	115	105
	150	145	125	115	115	115
	140	120	130	110	110	110
	155	125	120	120	120	110
	140	125	130	120	115	105
	140	130	125	115	105	105
	145	120	130	120	110	115
	125	130	140	125	120	110
	160	135	135	120	115	105
	155	125	150	125	110	110
	160	120	120	130	115	105
	160	115	130	120	120	105
	140	125	120	115	115	110
	165	120	125	115	125	105
	155	130	125	110	115	110
Average	148	126.7	129	118	115	108.3
Std Dev	11.5	7.45	7.79	5.72	4.83	3.5

APPENDIX B: IMAGE ANALYSIS RESULTS

```
        IMAGE ANALYSIS OF AFTER DEINKING


Paper ID          : Number 1
Material          : PRINTING
Special Note      : CHRIS HARRINGTON
Performed By      : STOOPS
Date              : Fri., Dec.  7. 1990

Threshold Level   : 40
Unit of Area      : MM²
Number of Bins    : 32
Bin Size          : 10.00
Bin Offset        :  0.00




      TABLE 1. Analysis Results


1) Number of Particles detected             4645
2) Total Areas of Particles (MM²) 1.7341E+0
3) Total Field Areas (MM²)             8.4376E+0
4) Percentage Area                         20.55
5) Minimum Area detectable (MM²)            0.00
6) Maximum Area detected (MM²)              0.05
7) Mean Area (MM²)                          0.00
8) Standard Deviation                       0.00
9) Parts per Million (MM²/mm²)        205516.00
```

```
        IMAGE ANALYSIS OF AFTER DEINKING


Paper ID          : Number 2
Material          : PRINTING
Special Note      : CHRIS HARRINGTON
Performed By      : STOOPS
Date              : Fri., Dec.  7, 1990

Threshold Level   : 40
Unit of Area      : MM²
Number of Bins    : 32
Bin Size          : 10.00
Bin Offset        :  0.00




        TABLE 1. Analysis Results

1) Number of Particles detected           3460
2) Total Areas of Particles (MM²) 7.8080E-1
3) Total Field Areas (MM²)        8.4669E+0
4) Percentage Area                        9.22
5) Minimum Area detectable (MM²)          0.00
6) Maximum Area detected (MM²)            0.01
7) Mean Area (MM²)                        0.00
8) Standard Deviation                     0.00
9) Parts per Million (MM²/mm²)        92220.20
```

```
      IMAGE ANALYSIS OF AFTER DEINKING


Paper ID           : Number 3
Material           : PRINTING
Special Note       : CHRIS HARRINGTON
Performed By       : STOOPS
Date               : Fri., Dec.  7, 1990

Threshold Level    : 40
Unit of Area       : MM²
Number of Bins     : 32
Bin Size           : 10.00
Bin Offset         :  0.00




        TABLE 1. Analysis Results


1) Number of Particles detected              1376
2) Total Areas of Particles (MM²) 2.2068E-1
3) Total Field Areas (MM²)        8.4666E+0
4) Percentage Area                           2.61
5) Minimum Area detectable (MM²)             0.00
6) Maximum Area detected (MM²)               0.01
7) Mean Area (MM²)                           0.00
8) Standard Deviation                        0.00
9) Parts per Million (MM²/mm²)           26064.50
```

```
      IMAGE ANALYSIS OF AFTER DEINKING


Paper ID            : Number 4
Material            : PRINTING
Special Note        : CHRIS HARRINGTON
Performed By        : STOOPS
Date                : Fri., Dec.  7, 1990

Threshold Level     : 40
Unit of Area        : MM²
Number of Bins      : 32
Bin Size            : 10.00
Bin Offset          :  0.00




         TABLE 1. Analysis Results


1) Number of Particles detected          1892
2) Total Areas of Particles (MM²) 3.1677E-1
3) Total Field Areas (MM²)          8.4660E+0
4) Percentage Area                       3.74
5) Minimum Area detectable (MM²)         0.00
6) Maximum Area detected (MM²)           0.01
7) Mean Area (MM²)                       0.00
8) Standard Deviation                    0.00
9) Parts per Million (MM²/mm²)       37412.60
```

```
         IMAGE ANALYSIS OF AFTER DEINKING


Paper ID         : Number 5
Material         : PRINTING
Special Note     : CHRIS HARRINGTON
Performed By     : STOOPS
Date             : Fri., Dec.  7, 1990

Threshold Level  : 40
Unit of Area     : MM²
Number of Bins   : 32
Bin Size         : 10.00
Bin Offset       :  0.00




          TABLE 1. Analysis Results


1) Number of Particles Detected          1519
2) Total Areas of Particles (MM²) 2.7175E-1
3) Total Field Areas (MM²)        8.4668E+0
4) Percentage Area                       3.21
5) Minimum Area detectable (MM²)         0.00
6) Maximum Area detected (MM²)           0.01
7) Mean Area (MM²)                       0.00
8) Standard Deviation                    0.00
9) Parts per Million (MM²/mm²)       32096.40
```

```
        IMAGE ANALYSIS OF AFTER DEINKING


Paper ID          : Number 6
Material          : PRINTING
Special Note      : CHRIS HARRINGTON
Performed By      : STOOPS
Date              : Fri., Dec.  7, 1990

Threshold Level   : 40
Unit of Area      : MM²
Number of Bins    : 32
Bin Size          : 10.00
Bin Offset        :  0.00



          TABLE 1. Analysis Results


1) Number of Particles detected            1504
2) Total Areas of Particles (MM²) 2.1657E-1
3) Total Field Areas (MM²)        8.4669E+0
4) Percentage Area                         2.56
5) Minimum Area detectable (MM²)           0.00
6) Maximum Area detected (MM²)             0.01
7) Mean Area (MM²)                         0.00
8) Standard Deviation                      0.00
9) Parts per Million (MM²/mm²)         25578.00
```