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The Effects of Carbon Particle Size on Deinking

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by

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Abstract

Different carbons deink to different brightness values. Deinking paper printed with inks composed of constant vehicles and different carbon pigments yielded a brightness range of 13.5 points.

General trends indicate that deinkability improves as carbon particle size increases and as structure level decreases. These trends are not conclusive, however, and significant variations from these trends were detected. It appears that the product of carbon particle size and structure level is more closely related to the final brightness than either particle size or structure level alone.

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Several factors affect how readily printed paper can be deinked. Some of these factors include the type of paper that is used, if the paper is coated or not, what kind of ink is used, and how the ink is applied and cured. There is a possibility that the size of the carbon particles used in printing inks could be another factor affecting paper deinkability. This suggested relationship has often been offered as a possible reason for the fact that European deinking sequences are sometimes more effective than similar American deinking sequences. No conclusive studies have ever been performed in this area even though it definitely warrants investigation.

The preparation and chemistry of various inks is a very broad and complex study in itself. There are two primary components in any ink. These are the pigment and the vehicle. The ink pigment is the portion that provides actual coverage over the substrate material that is printed. The ink vehicle is the component that causes the ink pigment to adhere to the sheet. Several other less important components are included in inks to contour the inks to specific uses. Some of these components include drying agents to hasten the ink cure time and gloss agents to control the gloss of the finished ink.

A wide spectrum of printing inks are available to fulfill the needs of specific coverage and also to be usable by different types of printing presses. There are three methods of printing that are commercially used to an extensive degree. Other printing methods exist, but they are either not used extensively, or they are combinations of these three basic methods. The first and oldest of these methods is letterpress relief printing. In this process, the area to be printed is reproduced on an impression cylinder which has raised areas corresponding to the areas to be printed. After applying ink to the raised areas, the paper is pressed against the impression cylinder, and an ink coverage varying from four to six microns in thickness is obtained.[1]

Gravure (intaglio) printing provides excellent printing qualities and is correspondingly expensive. Therefore, it is used only for very long printing runs where fixed production

costs can be recovered or when high quality is required. In this process, a metal cylinder plate is etched so that areas to be reproduced are a depressed area. Very liquid ink is used. The watery ink fills in the depressed areas and is transferred to the paper as it passes between the etched cylinder and impression cylinder. This method lays down an ink cover from ten to fifteen microns thick.[1]

The third major method of printing is called lithography or offset. This method utilizes the fact that water and oil do not mix. An offset plate is exposed and prepared so that areas to be reproduced are receptive to ink. The rest of the plate is covered with a thin layer of water solution. Ink is applied to the plate cylinder which rotates and transfers the ink to a rubber offset cylinder. Paper then passes between the offset and impression cylinders and is printed. The ink layer here is a very thin two to four microns.[1] The remainder of this survey will deal only with offset printing because it is the most popular of the three printing methods and also because it is the method that was used in this experiment.

Five major methods of drying printing inks exist. Discussion of two of these methods, radiation curing and heat polymerization, can be eliminated because of limited application to this study. The remaining three methods are absorption, evaporation, and oxidation.[2]

Absorption drying mechanisms are used primarily on uncoated groundwood stocks. Absorption inks do not really dry. Instead, the liquid vehicle of the ink migrates into the sheet so that there is a significant viscosity increase at the paper surface. Vehicles for absorption inks are primarily mineral oils and are completely hydrocarbons, so deinking sequences relying on alkaline saponification are not effective.[2]

Evaporation drying methods are used primarily on coated and uncoated magazine papers. Printing methods for which this drying method is used are gravure and heatset for web offset and letterpress. The vehicles are mainly rosin esters or metal resinates dissolved in appropriate solvents. Compositions vary widely, and deinking sequences generally require high temperatures and chemical concentrations to be effective.

Oxidation drying methods are applied to the drying of coated and uncoated paper and board printed on sheetfed offset presses. This is the drying method that will be used in the accompanying experimentation. Quick-set additives are used to enhance drying. Vehicles are typically binders of oil modified alkyds, oleoresinous varnishes, rosin esters or phenolic modified resin esters in a kerosene solvent. Deinking these inks should utilize saponification by strong alkalis at moderate to high temperatures.[2]

The pigment content of sheetfed offset oxidizing inks varies from 12 to 22 percent.[2] Various components are used as pigments depending on the color desired. Carbon black is the only pigment used in producing black inks, and it comes in many forms. These various forms have several measurable parameters which are specialized to the ink industry.

Carbon particle size, surface area, and structure level are three related but separate parameters. Carbon particle size refers to the mean particle diameter of individual carbon particles involved. This is determined by actual size estimation with high-magnification microscopes. Sizes used in ink manufacturing rarely exceed the range bounded by 15 millimicrons and 75 millimicrons.[3] Obtaining carbon particles with size less than 15 millimicrons requires excessive work, and using carbon particles with size greater than 75 millimicrons results in a very grey ink coverage. Most inks use carbon particles with an average diameter of 25 to 35 millimicrons.[4]

Surface area of carbon blacks is less commonly used than the particle size and structure level ratings, but is still useful. It is determined by nitrogen adsorption and is considerably larger than would be predicted by carbon particle size evaluation. It has been suggested that this difference is due to porosity in particle surface developed by oxidation of the carbon particles. This parameter varies over a much broader range than particle size does.[5]

Carbon black structure is a more commonly measured parameter than surface area. Like surface area, it varies much more than particle size. Structure is defined as the relative degree to which carbon black particles interlink during manufacture to form chainlike elements of varying length and complexity. There are two distinct types of structure. The first type is called primary or persistent structure. Primary structure is caused by discrete carbon

particles coupling into chains during the initial black formation. This structure cannot be significantly reduced by mechanical action. The other type of structure is called secondary or transient structure. Secondary structure is the result of the agglomeration of primary carbon structures into complex networks.[6] When inks are being milled or ground, the action is only decreasing the level of secondary structure.

A standard test is used to determine carbon structure level. Called the DBP (dibutyl phthalate) oil absorption test, it measures the relative interlinkage (structure) between individual carbon black particles. High structure levels are indicated by a high DBP value. A similar test is called the ASTM-DBP method, and it eliminates any variations in values of the test due to operator influence. The ASTM-DBP is very accurate and reproducible.[6]

Carbon blacks intended for use in ink formulations are commercially producible by two methods. The conventional method produces a grade called channel blacks. This method is being almost completely replaced by a newer method which produces a grade called furnace blacks. There are at least six reasons why channel blacks are being replaced:

1. Furnace carbons require much less work in the mixing stage than channel carbons do.
2. Vehicle demand is the amount of vehicle required to satisfy the adsorption and absorption properties of a given pigment. The higher the vehicle demand, the less

free vehicle there is in the system. Less free vehicle will result in higher viscosity and ink tack. Furnace carbons have much less surface area than channel blacks (for equal size particles), and therefore have a correspondingly lower vehicle demand. Lower vehicle demand will give the ink rheological advantages.

3. Furnace carbons have lower viscosities than channel carbons.
4. Furnace carbons impart less tack than their channel counterparts. These previous two advantages are primarily due to lower vehicle demand.
5. Furnace grades generally give better mileage than channel grades.
6. Since furnace grades have lower vehicle demand, they also have more free vehicle and a resultantly better smoothness. The better smoothness gives a much better gloss value.

Furnace grades are rapidly replacing channel grades, and furnace grades were used in this experiment for this very reason.[7]

The size of the carbon black particles used in an ink formulation will have a definite effect on the performance of the ink. There are at least four relationships between these two variables:

1. As carbon particle size decreases, more light is absorbed and less light is reflected. This makes finer carbon particle inks appear blacker and have greater covering power than their larger carbon particle counterparts.

2. Inks are usually plastic or pseudo-plastic liquids. Finer carbon particle inks have higher viscosities than larger particle inks. Again, this is primarily because the increased surface area requires more adhesive, leaves less free vehicle, and becomes more viscous.
3. More energy is required to premix fine particles than large particles. The small particles' large surface area has more adsorbed gases which must be displaced. Displacing this extra gas requires more work.
4. As particle size decreases, gloss and overall printability improves. This is because less vehicle penetrates into the paper with the finer particles. The vehicle at the surface then smoothes out the roughness caused by the carbon particles, decreases diffuse reflectance and increases spectral reflectance (gloss).

It is obvious that carbon particle size can play a crucial role in an ink's performance.[8]

Just as carbon particle size affects printing quality, so does the structure level. High structures tend to have better printing blackness than lower structure levels because of better dispersion during milling. A similar but slightly different way of saying this is that covering power increases with structure level because of the improved pigment dispersion. Accompanyiing these positive aspects of high structure are two negative aspects. One of these is that ink viscosity increases with structure level because of the increased oil consumption. The other disadvantage is that high level carbons tend to have greater smudge problems because they retain more oil on the printing surface. In

general, although high structure carbons disperse easily and give favorable printing results, viscosity and smudge problems reduce their favorability.[6]

Although a background education in inks and ink structures is necessary for an investigation into the effects of carbon particle size on deinking, a background education in the deinking of paper is also necessary. Deinking has advanced to the stage where it can be performed with reasonable success for most papers. Although the mechanisms utilized are partially understood, much still needs adequate clarification.

Deinking has traditionally been performed by washing the stock with large volumes of water after cooking the pulp in the presence of various chemicals. Flotation deinking cells now provide an alternative deinking method. In flotation cells, the ink particles are not washed from the pulp. Rather, air bubbles rising from the bottom of the cell collect ink particles at their surface and carry them to the water surface as they rise. The froth is then removed by paddles or skimmers.

The objectives of any deinking sequence is to break the paper apart into individual fibers and to remove ink particles from the slurry. Up to a point, all deinking sequences are very similar whether the ink will be removed by washing methods or by flotation methods. Basically the stock preparation involves pulping the paper and cooking it in the presence of chemicals and moderate to high temperatures. Significant differences exist between chemicals and temperatures used for deinking high groundwood paper as opposed to low groundwood paper, though.

There are several important factors to consider when cooking the pulp. Although some operations advocate pulping the paper before cooking it, this separation of tasks is generally shunned because more effective deinking is achieved by stabilizing the ink particles as soon as they are removed. If not stabilized immediately, the ink particles tend to redeposit, and they are often difficult to remove once they have redeposited. For the same reason, the stock should not be soaked before cooking.[9]

Cooking temperature is an important factor to control. Increased temperatures will decrease the length of the cooking cycle. High temperatures are favorable for three specific reasons. One is that higher temperatures soften the inks more. Increased temperatures also favor rapid defibering. The biggest advantage of high temperatures, though, is that it enhances chemical effectiveness by improving dispersion and stabilization. Papers with high groundwood content are generally cooked at temperatures varying from 100 to 160°F. Low groundwood papers are cooked at temperatures varying from 160 to 212°F. At such temperatures, batch cooking cycles are normally from 45 minutes to several hours long.[9]

The amount of agitation provided during deinking definitely influences deinking effectiveness. Agitation drives the cooking chemical into the paper and continually replaces the spent chemical located right at the paper surface. Increased agitation shortens the necessary cooking time and improves heat and chemical economy. Effective agitation is believed to improve a given pulp's strength and yield.[9]

The consistency of the pulp being deinked is another cooking factor to consider. Stock to be deinked is usually cooked at low density (five to seven percent). Some operations employ high density cooking, though (twenty to forty percent). Increasing cooking consistency will conserve chemicals and heat, decrease cooking time, and provide more effective defibering action. Basically, increasing cooking consistency is favorable up to the point where it impairs agitation.[9]

Multitudes of chemicals can be used in cooking. Very complicated and specialized formulations have been derived for cooking processes, and this represents a very complex field completely by itself. For ease of experimentation and to avoid digressing from this study's purpose, only four major cooking chemicals will be considered. These chemicals are sodium silicate, sodium hydroxide, sodium peroxide, and sodium carbonate. A few rules simplify chemical choice. Use of sodium hydroxide in cooking high groundwood paper should be avoided because of the yellowing effect the caustic will generate due to lignin presence. High groundwood content paper should be cooked in the presence of sodium peroxide at concentrations less than two percent. Peroxide not only serves as a bleaching agent to improve brightness, but it also solubilizes glue, casein, starch, and certain oils used in ink vehicles. Sodium silicate is used in conjunction with sodium peroxide because it buffers the solution in the correct range for peroxides. Triton X-100, a proprietary chemical which is primarily a detergent, is sometimes used to aid in collecting the ink particles once they are removed from the paper.

A generalized cooking chemical formulation for use in deinking high groundwood content paper is as follows: One to two percent sodium peroxide, three to five percent sodium silicate, and a very small amount of Triton X-100. Similarly, a generalized cooking chemical formulation for use in deinking low groundwood content paper is as follows: Two to four percent sodium hydroxide, two to four percent sodium carbonate, a little sodium silicate, and a very small amount of Triton X-100.[9]

There are a few basic steps to the cooking segment of a deinking process. The first is to add the paper and cooking chemicals in a Hydropulper. Water is added with continuous violent agitation until the desired consistency is reached. Cooking at the desired temperature is continued until it is determined complete. The stock is then run through a defibrator and diluted to the proper level for subsequent deinking operations.

While conventional methods of deinking stock by washing it on sidehill washers or other suitable devices are quite straightforward, flotation deinking is a complicated process. Flotation must be carefully controlled and involves extensive chemistry to work successfully. Of 32 variables involved in flotation deinking, 22 are controllable.[10]

Bubble formation is a difficult problem. Bubbles are formed as air is pumped into the pulp slurry through the bottom of the flotation cell. Frothers are surfactant chemicals that are used primarily to stabilize the bubbles once they are formed. The surfactant frothers have a hydrophilic end and a

hydrophobic end, and inherently orient themselves around air bubbles so that the hydrophobic end of the molecule is in the air of the bubble and the hydrophilic end is in the liquid of the surrounding water. This causes a negative charge to be distributed all around the outside of the bubble. The advantage of this charge is very important. Since all the bubbles are similarly charged, they are mutually repellent. This tendency keeps various bubbles from coalescing into larger bubbles which tend to rise rapidly and burst.[10]

Once stable bubbles are formed, the ink particles must be adhered to the bubbles so that they are lifted by the rising bubbles and skimmed off the top as dirty froth. Collectors (fatty acids and soaps) perform this duty well. Like frothers, collectors have hydrophobic and hydrophilic ends. Since ink particles tend to have positive charges, the negative end of the collector is attracted to the ink particles, and the hydrophilic-hydrophobic nature of the molecule draws it into the air bubbles like the frothers. In commercial flotation installations the foam removed from the top of 15 to 20 primary cells is collected and run through one secondary flotation cell to concentrate the waste products.[10]

The flotation deinking flow diagram varies from the washing flow diagram during points after the cooking stage. After cooking, stocks to be washing deinked are appropriately diluted and run over sidehill screens. In contrast, stocks to be flotation deinked undergo appropriate dilution (.5 to 1 percent consistency)[10] and the addition of frothers and

collectors after cooking. Then flotation deinking proceeds as explained.

Both deinking methods have unique advantages. Washing installations can boast two particular advantages over flotation installations. One is that the initial installation cost is considerably lower. More important than this, though, is the second advantage that washing provides a cleaner final stock than flotation does. On the other hand, flotation has three specific advantages over washing methods. Since flotation selectively removes ink particles, it leaves more fibers, filler, and fines in the stock so that it ends up with higher yield than washing techniques. A second slight advantage is that chemical and steam costs are lower for flotation than for washing. The last advantage is very important, particularly now that environmental control is of prime interest. The waste volume from flotation systems is much smaller, more concentrated, and more easily treated than the waste from similar size washing operations.[11]

One study vaguely related to this investigation was performed by G. Galland, E. Bernard, and G. Sauret in 1976. Primarily these men were interested in how different printing techniques affect deinking. In so doing, they approached the subject of this report because they used varying inks that were appropriate to each specific type of printing. Some of the conclusions reached by this survey are listed below.

1. Deinking newsprint is very different from deinking other grades of paper, and this is primarily because of the

ink drying mechanism used. Newsprint pigments are attached only because of a viscosity increase caused by filtration of the vehicle into the substrate. On the other hand, most other inks undergo chemical and physical modifications which make them harder to remove.[12]

2. The nature of the ink resins used is very important in deinkability. Resins derived from colophony, siccative oils, or alkyds are easily broken down because they are alkali saponifiable. On the other hand, resins derived from cellulose derivatives or certain petrol resins are difficult to break down and remove.[12]

3. The following results were obtained by deinking all stocks with a flotation cell using a deinking solution of two percent sodium peroxide, 1.25 percent sodium trisilicate, and one percent fatty acid.[12]

Grades	Whiteness of non-printed paper*	Whiteness of printed paper**
Letterpress newsprint	53	52
Offset newsprint	52	49
Rotogravure on uncoated	62	53
Rotogravure on coated	72	69
Rotary offset on uncoated	85	52
Rotary offset on coated	76	70

* After disintegration in water

** After flotation deinking

The study most closely related to this subject was performed by two German chemists. Their study compared deinkability of American inks versus deinkability of German inks. Variables

that were considered in that study included the carbon blacks, vehicles, soluble dyes, and dispersing methods utilized.[13]

The variation in types of carbon blacks used did not consider the carbon particle size, but did compare carbons produced by several different methods. Results of this study definitely indicated that German carbon black inks deinked to a much higher brightness than American carbon black inks. Since the vehicles and deinking sequences used were identical for each of the inks, the study concluded that the varying factor was the particle size and the varying wettability of the different carbon blacks.[13]

Other conclusions of this study indicated German inks are more easily deinked than American inks. One contributing factor was that the vehicles utilized made significant differences. German inks use easily saponified colophony-stearine pitch varnish vehicles. The American inks that were considered used more difficult-to-saponify asphate varnish vehicles. A second contributing factor in this category involves the techniques used in dispersing the carbon black particles in the vehicle. The more intensive the dispersion required, the more difficult the ink becomes to deink. This study indicated American carbons utilize more intensive dispersion than most German carbons.[13]

Little information is known on the effect of carbon particle size on paper deinkability. Sufficient material is available on inks, carbon structures, and deinking methods, though, to allow for the design and execution of a project aimed at finding more information in this field.

Experimental Procedure

Materials used:

1. Paper: The paper that was selected was a low groundwood, uncoated, filled offset printing paper. It contained 25 percent groundwood and 12.3 percent filler. The basis weight was 56 pounds per 25 inch by 38 inch ream, and its brightness was 65.5. Low groundwood was chosen in preference to high groundwood because of much greater economic incentive to deink the higher value low groundwood paper.

2. Ink materials: Inks to fit the needs of this experiment are not commercially available. They had to be specially prepared by grinding specific carbons into a constant ink vehicle.

   a. Carbon particles: Cabot Corporation supplied the seven following carbons.

Mean particle diameter	Structure level	Ink number
18 mu	High	1
17 mu	Low	2
27 mu	High	3
27 mu	Medium	4
25 mu	Low	5
75 mu	High	6
75 mu	Medium	7

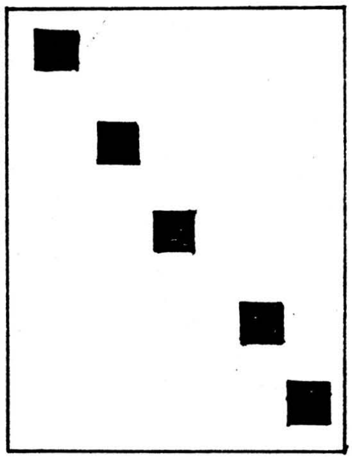
Inks will be referred to by these numbers from now on.

These particle sizes were chosen because 15 and 75 mu represent the limits of the commercially used particle size range, and 25 mu represents the most common particle size used in inks.

b. Vehicle: The vehicle used was an isophthalic alkyd, and was maintained constant throughout the entire experiment. Sun Chemical Corporation provided the vehicle, assistance, and equipment necessary to grind the pigment and vehicle together.

Experimental procedure:

1. Prepare a printing plate for a Multilith 2000 offset printing press: The plate was made using facilities at the Printing Department at Western Michigan University. The same plate was used for all inks. The material that was selected to be printed was covered with type and with five one-inch squares. The squares were arranged on the $8\frac{1}{2}$" by 11" sheet as shown. These blocks were solid black and were placed there to allow densitometer readings to be taken on the printed material. The densitometer reads out in ink density or coverage so that constant readings will assure equivalent ink coverage throughout the experiment. Placing the blocks on a diagonal pattern like this allows ink coverage to be maintained constant in all directions. See the appendix, section V for a sample of the printed material.



2. Prepare the printing inks: The seven inks were ground out at Sun Chemical Corporation in Kalamazoo, Michigan.

One pound of each ink was produced. The following preparation format was used.

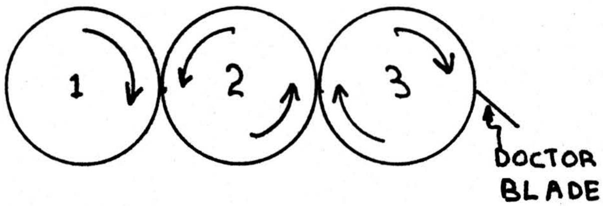
a. Four ounces of each carbon black was weighed out.

b. Twelve ounces of isophthalic alkyd vehicle was added to each of the above pigments.

c. The two components were roughly blended together by hand.

d. After a relatively smooth mixture was obtained, the ink was ground out on a standard laboratory three roll mill. A three roll mill is constructed as the diagram indicates:

   1. The unground ink was added in the nip formed by rolls 1 and 2. The rolls are precisely machined metal cylinders that can be adjusted to vary the clearance between the rolls.



   2. The ink passes through the next nip and is removed from roll 3 by a doctor blade. This ink is then passed through the process again until a proper grind is obtained.

e. All inks were passed through the three roll mill twice at a coarse setting and twice with a finer clearance. The only exception to this was with ink number six. It only needed to be passed through the fine grind once.

f. 1.1% (5.0 grams) of cobalt drier was added and manually mixed with each ink after grinding.

3. Print the paper: All samples were printed on a Multilith 2000 printing press. No press parameters were altered between runs. All inks except ink number four were printed on the same day to eliminate any aging effect of the ink on the paper. With all inks except number four, 90 sheets (450 grams) were printed. With ink four, 300 sheets (1500 grams) were printed. Extra samples were printed in this case to determine a desirable deinking technique. (This will be discussed later.)

4. Take densitometer readings: As explained before, these readings were taken to assure that a constant amount of ink and carbon were applied to each sheet. See the appendix, section IV for further details on densitometer readings.

5. Determine a desirable deinking process: The purpose of this step is not to develop the best method available to deink this stock. Rather, its purpose is to develop a relatively good deinking sequence and maintain this sequence as a constant throughout the rest of the experiment.

Six deinking trials were considered. In all cases, 20 sheets (100 grams) of printed paper were defibered at 6 percent consistency in cool tap water in a Waring Blendor at a constant speed for a constant time of 2.5 minutes. After defibering, the stock was heated up to

the desired cooking temperature in a two liter stainless steel vessel while receiving constant agitation supplied by a heavy duty Waring Blendor motor and a suitable impeller. Once the desired temperature was reached, cooking chemicals were added, and temperature and agitation were both maintained constant throughout the cook. All of these variations were performed on 27 mu, medium structure level ink. The following variations were examined.

Variation number	% NaOH added	% Na_2CO_3 added	6 drops Triton X-100 ?	Cooking temp.	Cooking time	Deinking Technique
1	2%	4%	No	160°F	45 min.	Sidehill
2	4%	2%	No	160°F	45 min.	Sidehill
3	3%	3%	Yes	160°F	45 min.	Sidehill
4	4%	2%	No	190°F	45 min.	Sidehill
5	4%	2%	No	190°F	60 min.	Sidehill
6	4%	2%	Yes	190°F	45 min.	Flotation

Results of these runs are presented on page 25. On the basis of these results, the following cooking sequence was chosen:

Cooking chemicals: 4% NaOH, 2% Na_2CO_3, 6 drops Triton X-100

Cooking temperature: 190°F

Cooking time: 45 minutes

Deinking technique: Flotation cell

The same general cooking conditions as explained in the previous paragraph were maintained throughout the entire experiment. The flotation deinking was done in a Voith

laboratory flotation cell. Flotation consistency was at 0.6 percent, and was performed for twelve minutes. No extra chemicals were added to serve as frothers or collectors. For further details on this deinking cell, see the appendix, section VI.

6. Deink the various printed samples: All seven samples were deinked under the same conditions as described above. At least three runs were made on each printed sample, and usually four were made. When four runs were made and one of the runs had results significantly different from the other three, that run could be dropped, and three good values were still available.

7. Form handsheets: Six Noble and Wood handsheets were made for each run. A basis weight of 60 g/m^2 was maintained. Since Noble and Wood handsheets inherently wash the pulp due to its high dilution, six 300 g/m^2 Buchner pads were also formed for each run. This method does not wash the pulp as well and therefore retains many more fines.

8. Test the sheets for optical values: A Technidyne Corporation Brightness Tester and Colorimeter was used. Brightness was the main test that was run, and brightness values were taken for the wire sides and the "felt" sides of both the Noble and Wood handsheets and of the Buchner pads. Color determinations were made at all four positions to determine if various deinking techniques tended to yellow the stock. Color values are reported as a combination of

two numbers. These numbers are the dominant wavelength and purity. See the appendix, section VII for further details on this brightness and color tester and on color determination.

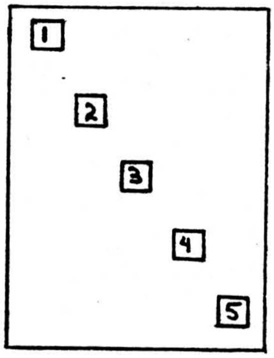
9. Make one control deinking run: Some of the original paper without printing was defibered and run through the entire flotation deinking sequence. The purpose of this was to determine the ultimate achievable brightness by the deinking technique.

RESULTS PRESENTATION

Extensive data tables are available for examination in the appendix, sections I through IV. The data presented in this section is a summary of these more extensive tables.

Inks will be referred to according to the chart on page 17.

A. Densitometer readings: Five one inch squares were printed on the paper. These squares were numbered according to the following position grid.



Densitometer Readings

Ink No.	Pos.1	Pos.2	Pos.3	Pos.4	Pos.5	Overall Values	
1	1.33	1.31	1.31	1.32	1.34	1.32	(1)
	.0195	.0358	.0164	.0166	.0124	.0130	(2)
2	1.29	1.24	1.26	1.27	1.30	1.27	(1)
	.0279	.0523	.0336	.0258	.0163	.0239	(2)
3	1.32	1.30	1.33	1.33	1.35	1.33	(1)
	.0241	.0342	.0165	.0174	.0108	.0182	(2)
4	1.27	1.20	1.21	1.23	1.26	1.23	(1)
	.0517	.0734	.0678	.0628	.0305	.0305	(2)
5	1.31	1.25	1.26	1.20	1.27	1.26	(1)
	.0248	.0691	.0524	.0664	.0229	.0396	(2)
6	1.30	1.25	1.27	1.27	1.29	1.28	(1)
	.0394	.0339	.0260	.0226	.0191	.0195	(2)
7	1.29	1.23	1.22	1.21	1.24	1.24	(1)
	.0270	.0408	.0406	.0323	.0246	.0311	(2)

(1) = Mean value

(2) = Standard deviation

B. Results of experimentation leading to choice of deinking sequence to be used: This is a summary of the optical results obtained from variations one through six as explained in the experimental procedure, section V.

*Variation Number	BWS brt.	BFS brt.	N&WWS brt.	N&WFS brt.	Mean brt.	Mean DWL	Mean Purity
1	59.3	60.0	62.7	63.6	61.4	570	.073
2	60.5	60.4	62.3	63.9	61.8	572	.085
3	61.8	60.9	64.6	65.5	63.2	572	.096
4	61.3	61.0	64.5	65.5	63.1	572	.085
5	60.2	58.6	64.9	64.7	62.1	571	.079
6	65.0	64.8	65.1	67.2	65.5	567	.063

*Heading abbreviation explanation:

BWS brt. = Brightness value obtained from the side of Buchner pads closest to the filter paper.

BFS brt. = Brightness value obtained from the side of Buchner pads farthest from the filter paper.

N&WWS brt. = Brightness value obtained from the wire side of Noble and Wood handsheets.

N&WFS brt. = Brightness value obtained from the felt side of Noble and Wood handsheets.

Mean brt. = Mean brightness value determined from these four previous values.

Mean DWL = Mean dominant wavelength value

Mean Purity = Mean purity value

Note: For all six variations, paper printed with 27 mu, medium structure level ink was used.

C. Results of deinking the stock printed with various inks:

The following summary of brightness data was obtained.

Table C-1

*Ink No.	Read. Posi.	Run 1	Run 2	Run 3	Run 4	Means
1	BWS	62.3	50.5	61.1	61.5	58.9
(18 mu)	BFS	61.9	51.5	61.8	61.8	59.2
(High)	N&WWS	61.5	54.9	61.3	61.8	59.9
	N&WFS	62.6	59.8	64.7	63.5	62.7
2	BWS	58.0	56.9	51.7	57.7	56.1
(17 mu)	BFS	58.7	56.1	51.1	57.2	55.8
(Low)	N&WWS	61.3	57.8	54.8	59.3	58.3
	N&WFS	69.0	63.0	60.1	63.9	62.8
3	BWS	56.6	-	53.2		54.9
(27 mu)	BFS	58.5	58.5	54.0		57.0
(High)	N&WWS	58.8	57.9	56.8		57.8
	N&WFS	63.5	63.3	63.0		63.3
4	BWS	65.0	57.3	58.3	58.0	59.7
(27 mu)	BFS	64.8	57.3	58.5	58.0	59.7
(Medium)	N&WWS	65.1	57.5	58.3	57.9	59.7
	N&WFS	67.2	63.5	63.1	63.0	64.2
5	BWS	64.2	66.5	58.5	65.1	63.6
(25 mu)	BFS	64.7	66.5	57.4	65.8	63.6
(Low)	N&WWS	66.6	64.9	59.4	65.6	64.1
	N&WFS	68.1	68.0	64.2	67.8	67.0
6	BWS	-	47.6	45.3	47.9	46.9
(75 mu)	BFS	49.8	50.4	46.8	49.1	49.0
(High)	N&WWS	52.6	52.9	47.1	52.6	51.3
	N&WFS	57.4	60.0	57.4	58.3	58.3
7	BWS	65.1	62.0	54.6	63.8	61.4
(75 mu)	BFS	64.9	62.1	54.2	63.0	61.1
(Medium)	N&WWS	65.8	63.3	57.0	64.4	62.6
	N&WFS	67.9	66.5	62.1	67.3	66.0

*Ink numbers refer to those outlined in the experimental procedure section on page 17.

BWS: The side of the Buchner pad nearest to the filter paper.

BFS: The side of the Buchner pad farthest from the filter paper.

N&WWS: Noble and Wood handsheet wire side.

N&WFS: Noble and Wood handsheet felt side.

A more useful variation of this previous chart can be obtained by using an average value for each run that is obtained by averaging the four position readings presented in Table C-1.

Table C-2

Ink No.	Run 1	Run 2	Run 3	Run 4	Mean Value
1	62.1	54.2	62.2	62.2	60.2
2	60.5	58.4	54.4	59.5	58.2
3	59.4	59.9	56.8		58.7
4	65.5	58.9	59.6	59.2	60.8
5	65.9	66.5	59.9	66.1	64.6
6	53.3	52.7	49.2	52.0	51.8
7	65.9	63.5	57.0	64.6	62.8

Some of the values in this chart are clearly very different from the other three values for that ink. The "bad" values are readily recognizable. If these values are rejected and new means and standard deviations are calculated, it can be shown that these values that were just thrown out are outside three sigma limits. When the bad values are eliminated, the following data summary is obtained.

Table C-3

Ink No.	Run 1	Run 2	Run 3	Run 4	Mean Value $\pm$ 3S
1	62.1		62.2	62.2	62.2 $\pm$ .173
2	60.5	58.4		59.5	59.5 $\pm$ 3.15
3	59.4	59.9	56.8		58.7 $\pm$ 4.99
4		58.9	59.6	59.2	59.2 $\pm$ 1.05
5	65.9	66.5		66.1	66.2 $\pm$ .917
6	53.3	52.7		52.0	52.7 $\pm$ 1.95
7	65.9	63.5		64.6	64.7 $\pm$ 3.60

Comparison of Table C-2 and Table C-3 definitely shows that all rejected values were significantly outside of the three sigma limits established and that rejection of those values is justified. Table C-3 is the primary data chart that will be used in analyzing the results of the entire experiment.

D. Optical values of the original paper: The following chart summarizes the optical results of the original paper without printing.

Original Paper's Optical Values

Conditions	Mean brightness	Mean dominant wavelength	Mean purity
Original paper	65.5	562	.258
Water repulping	65.4	578	.118
Deinking procedure	71.2	570	.073

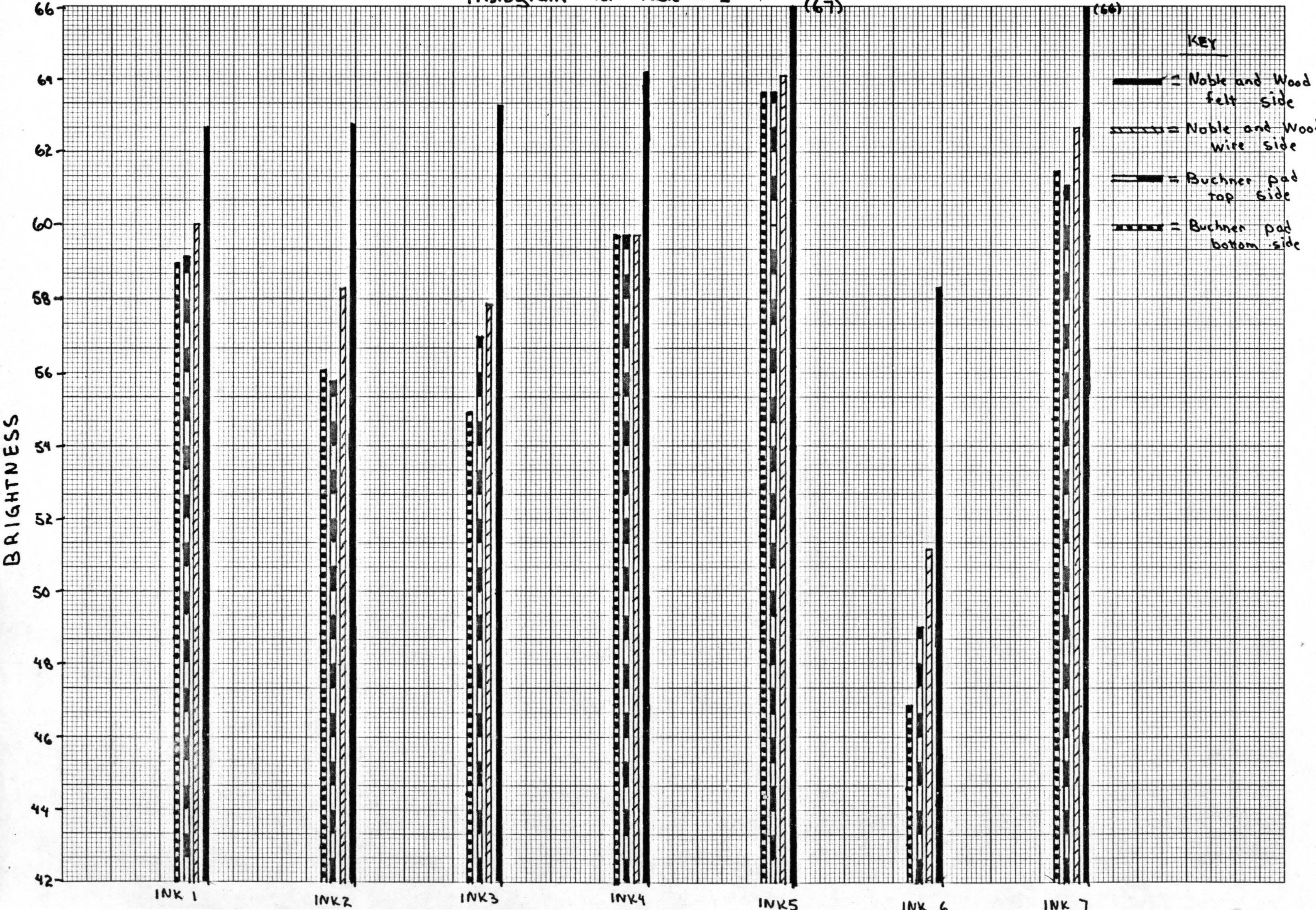
Condition explanation:

Original paper: Sheets of the original paper.

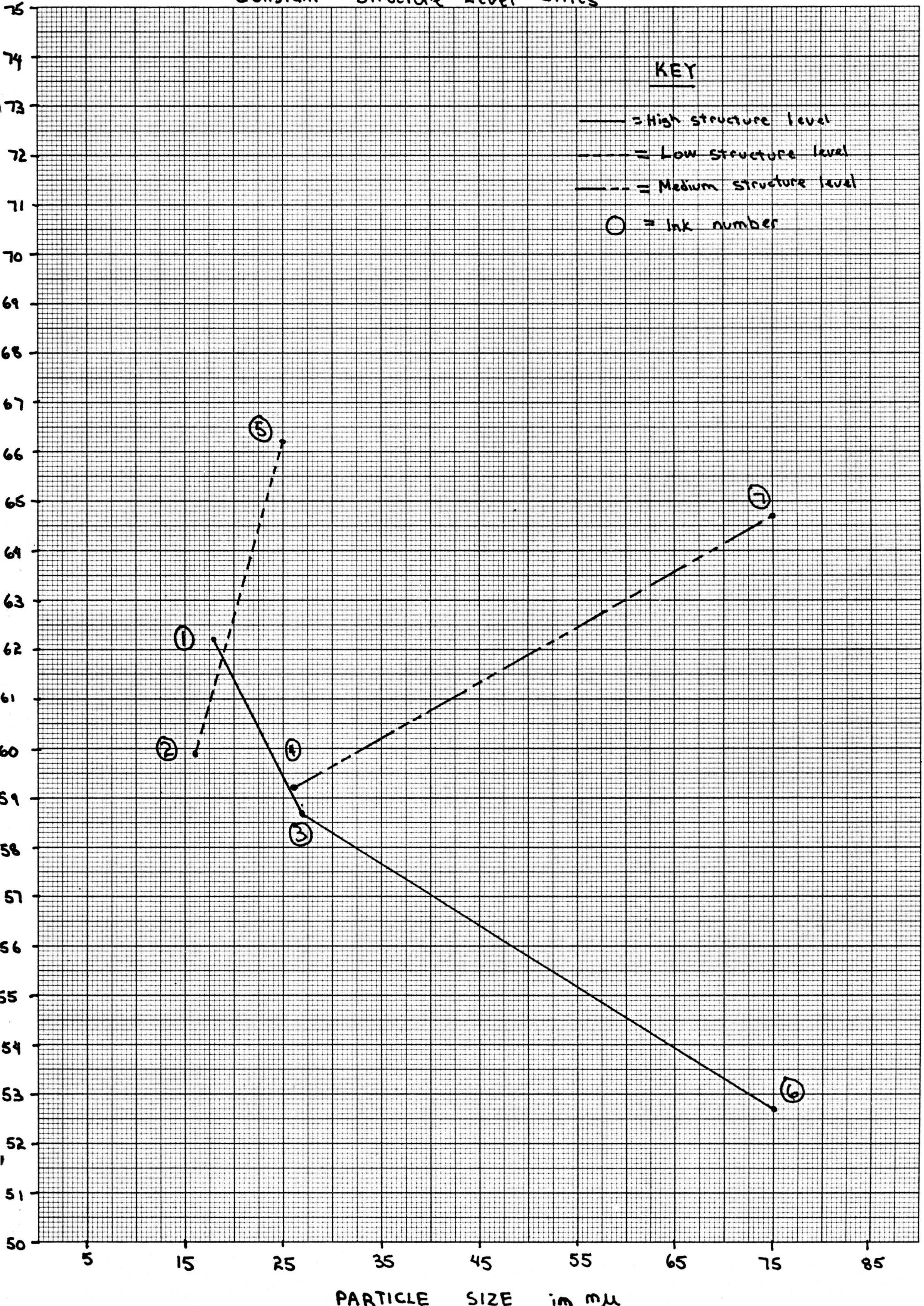
Water repulping: Sheets of the original paper after being defibered and reformed as Noble and Wood handsheets.

Deinking procedure: Sheets of the original paper that were defibered and run through the entire flotation deinking process before being formed as Buchner pads and Noble and Wood handsheets.

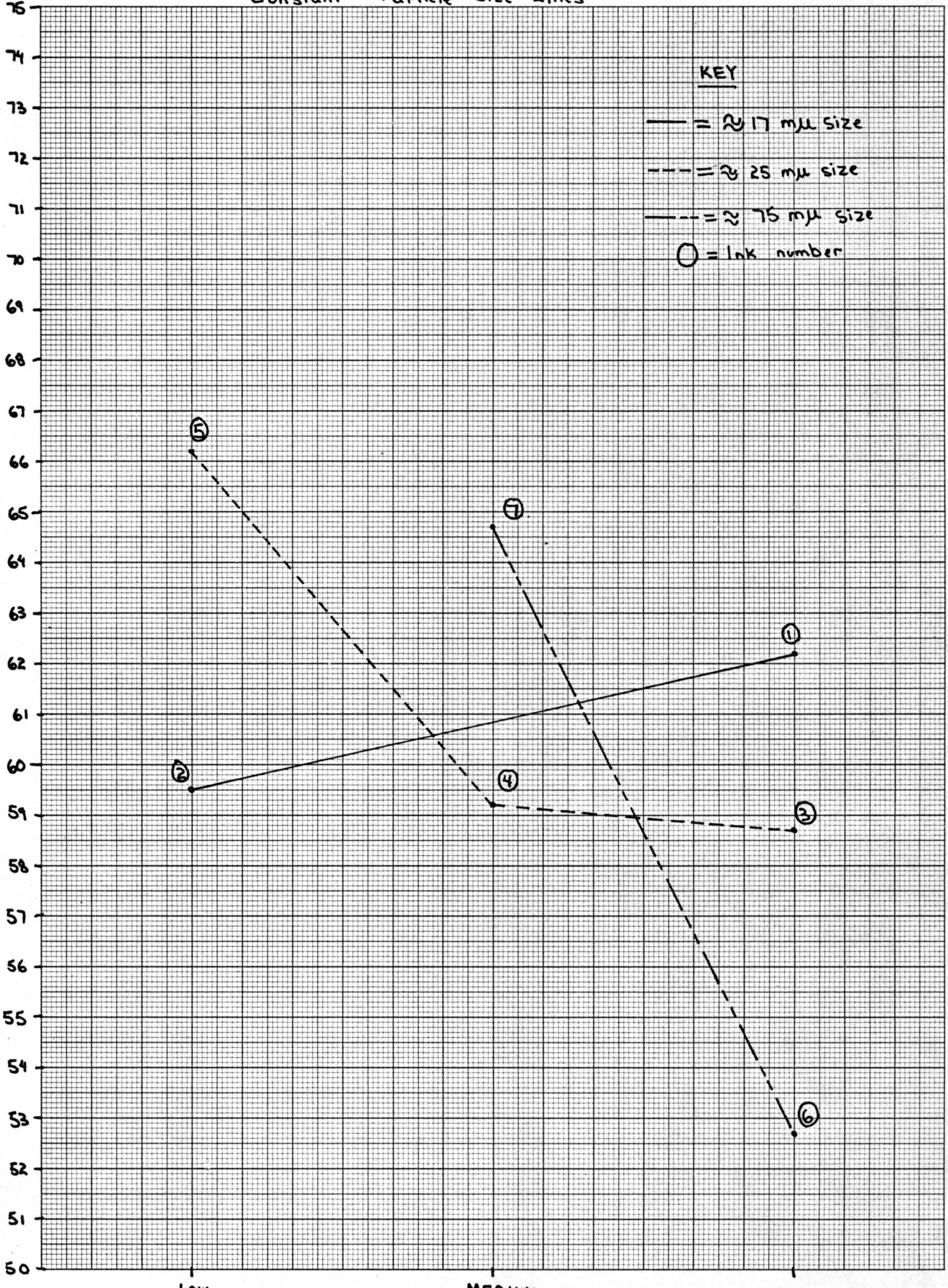
Histogram for Table C-1



Constant Structure Level Lines



Constant Particle Size Lines



STRUCTURE LEVEL

Discussion of Results

Different brightness values are obtained with different carbons. An average brightness spread of 13.5 points between different carbons (carbons five and six) was obtained.

Analyzing the Constant Particle Size Lines chart shows that clearcut trends are not easy to detect. Basically the chart can be generalized to state that for a given particle size, deinkability improves as the structure level decreases. The 17 to 18 mu particle size curve deviates from this trend.

Studying the Constant Structure Level Lines chart shows a similar lack of clearcut trends. Gross trends, though, would indicate that for a given structure level, deinkability improves as particle size increases. The high structure level curve deviates from this trend.

These two trends are confusing because they are in opposing directions. A possible explanation is afforded by manufacturer specifications for the various carbons. Cabot Corporation provided the following data. (The oil (DBP) absorption test is used to give an indication of carbon structure level and also of relative ink viscosity.)

Carbon Particle Data

Ink No.	Particle size (in mu)	Surface area (m^2/g)	Oil Absorption (cc/ 100 g)	Structure Level	Brightness
1	18	200	117	High	62.2
2	17	210	68	Low	59.5
3	27			High	58.7
4	27	85	≈ 100	Medium	59.2
5	25	94	70	Low	66.2
6	75			High	52.7
7	75	25	70	Medium	64.7

Some data is not available for this chart.

Examination of these numbers to detect some predictable brightness values yields some interesting results. Expected trends do not work particularly well. For example, since structure level appears to be inversely related to brightness and since particle size appears to be directly related to brightness values, one might expect the ratio of particle size to oil absorption (since oil absorption is an indication of structure level) to be proportional to brightness values. This does not happen.

A possible manipulation to predict brightness is afforded by the following equation:

$[(\text{Surface area})(\text{particle size}) \propto \text{brightness values}]$ for constant particle size groups.

Equation Predictions

Ink No.	Particle Size	Surface Area	Predicted Value	Brightness
1	18	200	3600	60.2
2	17	210	3570	58.2
4	27	85	2295	60.8
5	25	94	2350	64.6
7	75	25	1875	62.8

This trend may be coincidental and cannot be stated to be accurate with such a small population of data. If more data were available, it would be wise to try curve fitting and line estimation techniques to develop a more accurate prediction equation.

The differences between carbon particle size and structure level must be fully understood. Carbon particle size refers to the ultimate particle size of an individual particle. Particle size is estimated by the mean arithmetic diameter as determined by analysis with an electron microscope. Structure level is the degree to which these individual carbon particles are agglomerated together. A high structure level refers to a lengthy agglomeration of these particles, and a low structure level refers to a much smaller agglomeration of these particles. A high structure level carbon is much larger than a low structure level carbon, and is independent of ultimate carbon particle size. Interpreting particle size as the approximate mesh screen that the particle will just pass through is incorrect. An individual particle is never found. Individual particles are always agglomerated together into much larger effective particles whose size is crudely estimated by structure level.

In all cases, Noble and Wood handsheets were significantly brighter than Buchner pads. Handsheet formation inherently washes the stock and allows for carbon particles that were not removed during the flotation process to be removed through the wire. Buchner pad formation on the other hand uses a pulp slurry taken directly from the flotation cell with no additional dilution and it also uses filter paper with a much finer pore size than that provided by Noble and Wood handsheet wires, so it retains many more carbon particles in the pad.

Two-sidedness was evidenced in handsheet and pad testing. The felt (or top) side develops a higher brightness value than the wire side in all cases. This trend was quite pronounced on the Noble and Wood handsheets. Such a trend indicates that carbon particles remaining in the deinked stock preferentially locate themselves closer to the wire side of the sheet during formation.

These brightness differences indicate that improved washing techniques would increase the overall brightness. If the stock were washed as well as it could be, there would be no two-sidedness, and Buchner pads would be as bright as Noble and Wood handsheets.

Excellent agreement of results was obtained between the various runs for any given ink. Reproducible results are substantiated in Table C-3. These constant results and close sigma limits were obtained because experiment controls were carefully maintained.

Densitometer readings were taken on all the stocks printed with the various inks to assure that equivalent amounts of carbon were applied to each sheet. Average densitometer readings varied between the ranges of 1.23 and 1.33. This range is quite small, and the variations are related to particle size. In accordance with findings from the theoretical discussion, the readings indicated that fine particles give better coverage and slightly darker (higher) readings than larger particles. One would expect fine particle size readings to be slightly higher than coarse particle size readings for

equivalent carbon coverage. Through the combination of this effect and the fact that the variations were quite small, the study can be treated as if the amount of carbon applied to each sheet is constant.

Other control factors were maintained very well. All the carbons were supplied by the same manufacturer, and all carbons were ground into a constant vehicle in the same proportions. All carbons received similar grinding. All inks were applied with the same press under identical conditions, and all of the printed paper was stored in the same location. Deinking sequences were the same for all cooks. Testing procedures were extremely constant.

Control of the flotation cell proved to be rather touchy. Bubble size is crucial to good deinking. If bubbles become oversized, they not only float all ink particles, but they will also scour the water of fibers. Since the cell used a recirculating design, a pump at the bottom of a reservoir is used to pump the stock back into the cell. If this reservoir is not kept flooded with at least one-quarter to one-half inch of liquid, the pump entrains air and causes oversized bubbles to form. Then all stock is floated off with the ink rejects.

A few remaining unrelated but interesting results from this experimentation can be summarized as follows.

1. Color variation between different runs was minimal. All stocks were testing out to have a dominant wavelength of about 570 nanometers and a purity of 7 to 10 percent, so color determinations were discontinued.

2. Flotation deinking is quite selective at removing only ink particles. Fines and filler particles are not removed from the stock, so a very low freeness stock that drains quite slowly is obtained when flotation deinking is utilized.
3. The ultimate brightness that should be achievable during this experiment is estimated at about 71.2. This is the value that was obtained when the original, unprinted stock was run through the entire deinking process and tested for brightness. Printed paper deinked to brightness values of 52.7 to 66.2.

Conclusions

This experimentation demonstrated that the type of carbon used in an ink definitely affects how well printed papers will deink. General trends implied that deinking improves as particle size increases and as structure level decreases, but this is not conclusive. The product of size and surface area appears to be more closely related to final brightness than either particle size or structure level alone.

Noble and Wood handsheets are much brighter than Buchner pads. This is because formation on the Noble and Wood sheetmold dilutes the stock much more and washes it much better than formation with Buchner funnels. This gross dilution allows for many more fines and ink particles to be washed out of the slurry.

Felt (or top) side brightnesses are much higher than wire side brightnesses. This indicates that the dense carbon particles preferentially distribute themselves close to the wire side. This trend is more pronounced in Noble and Wood handsheets than in Buchner pads because the much greater dilution allows for greater movement potential and preferential distribution with Noble and Wood sheets.

Recommendations

Before the trends that have been indicated here can be conclusively stated as being true, several more inks with various carbons should be analyzed. Although this study has indicated general trends, the only way the information can be put to use is if there are many more values to help substantiate any statements.

A useful extension of this study would be to measure the effective particle size of carbon agglomerations after they have been ground into inks. The inks could be cut very heavily with blanket wash, and the resultant mix could be measured with an electron microscope. This is the only way to determine what effective size particles are being removed by the deinking process.

Use of a brighter original paper might be desirable. It was difficult to determine if it was the paper that was keeping the deinked stock brightnesses down in the low sixties or if this brightness level was the ultimate level achievable from these inks. Brighter paper may extend the range obtained from the brightest sample to the least bright sample.

The type of carbon used in inks affects printers very little but it can affect deinkers tremendously. Cooperation between ink manufacturers, printers, and deinkers would be very desirable. According to this study, the best ink to use would be one utilizing low structure level, 25 mu particle size carbon, and the worst ink to use would be high structure level, 75 mu particle size carbon.

Sincere thanks are due to Lyman Aldrich of Western Michigan University, Mark Fuchs of Sun Chemical Corporation, and Philip Goulston of Cabot Corporation for their generous support of this experiment.

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APPENDIX

The purpose of this appendix is to include the raw data and other lengthy details. This data is too lengthy to include in the main body, but deserves to be available.

I. Preliminary cooks used to determine what deinking technique to use. In all cases, 100 grams of paper printed with medium structure level, 27 mu particle size ink was used.

A. Cook 1A

Chemicals: 2% NaOH, 4% Na_2CO_3

Cook time: 45 minutes

Cook temperature: 160°F

Deinking technique: Sidehill washer

Brightness values:

	Buchner Wire Side			Buchner Felt Side			Noble and Wood Wire Side			Noble and Wood Felt Side		
	59.6	59.7	59.9	60.9	59.8	60.2	62.3	62.2	62.3	63.1	62.9	63.5
	58.5	59.7	58.6	59.7	60.1	59.2	63.6	63.3	63.6	63.7	63.5	63.8
	59.6	58.8	59.1	60.5	60.7	60.6	62.5	62.7	63.0	64.1	63.8	64.1
	59.9	59.1	59.6	59.9	59.7	60.6	62.4	62.5	62.7	64.0	64.1	63.9
	59.5	59.2	58.6	59.9	60.0	58.8	62.4	62.4	62.4	63.6	63.0	63.5
Averages:		59.3			60.0			62.7			63.6	

Color values:

Filter 2	11.3	11.2	11.3	11.6	11.3	11.5	12.0	12.1	11.9	12.2	12.0	12.0
Filter 3	51.8	51.7	52.1	53.0	51.3	53.0	55.8	55.9	56.3	56.1	56.8	56.2
Filter 4	66.2	64.2	64.1	66.2	66.4	66.1	70.7	69.6	69.3	69.9	70.2	70.5
Filter 5	69.5	71.0	69.1	70.0	69.8	69.8	72.8	73.0	74.1	74.6	73.6	74.4
X_{CIE}		63.13			63.90			68.00			68.44	
Y_{CIE}		64.83			66.23			69.87			70.20	
Z_{CIE}		69.87			69.87			73.30			74.20	
x		.3191			.3195			.3220			.3216	
y		.3277			.3312			.3309			.3298	
Dominant Wavelength		570			570			570			570	
Purity		.0727			.073			.073			.073	

B. Cook 1B

This cook is the same as cook 1A, but the stock was washed a bit better on the sidehill washer.

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	60.0	59.3	58.6	56.9	57.6	57.3	61.8	61.8	62.6	63.5	63.8	63.2
	58.8	58.4	59.5	56.7	56.7	57.1	61.9	61.8	61.9	63.2	62.8	62.6
	57.4	59.0	58.4	57.4	57.1	57.4	62.2	61.7	61.9	63.0	63.2	63.7
	59.0	58.2	58.3	55.9	57.7	58.7	61.7	61.5	61.5	63.7	63.6	62.4
	58.3	56.6	59.3	56.0	54.7	54.6	60.9	61.6	61.0	63.7	63.3	63.8
Averages:		58.6			56.8			61.7			63.3	

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	11.1	10.7	10.6	10.6	11.2	11.2	11.6	11.8	11.7	12.0	12.1	12.0
Filter 3	48.8	50.9	49.3	50.6	50.8	49.4	55.2	55.7	55.5	56.4	56.2	56.2
Filter 4	63.5	61.9	63.5	63.5	62.0	63.2	67.7	68.5	68.5	69.9	70.3	69.1
Filter 5	68.2	64.3	66.2	67.8	66.2	66.9	71.9	72.3	72.1	73.5	73.9	74.2
X_{CIE}		61.3			60.5			67.2			68.3	
Y_{CIE}		62.9			63.0			68.3			69.8	
Z_{CIE}		67.0			66.2			72.1			73.9	
x		.321			.319			.324			.322	
y		.329			.332			.329			.329	
Dominant Wavelength		570			570			574			570	
Purity		.073			.073			.118			.073	

C. Cook 2A

Chemicals: 4% NaOH, 2% Na_2CO_3

Cook time: 45 minutes

Cook temperature: 160°F

Deinking technique: Sidehill washer

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	60.3	59.1	60.5	60.3	60.2	60.1	61.6	61.7	62.5	64.0	63.9	64.4
	60.3	60.8	60.8	60.4	60.6	61.3	63.2	62.4	63.0	63.6	64.3	63.7
	60.4	61.0	61.4	60.8	60.4	60.1	62.1	62.2	62.9	63.9	64.0	63.7
	60.4	60.5	60.3	59.9	60.1	60.2	62.5	61.9	62.2	63.9	63.7	63.5
	60.8	60.4	60.9	60.8	60.7	60.2	62.5	62.1	62.3	63.8	63.6	64.1
Averages:	60.5			60.4			62.3			63.9		

Color values:

	BWS	BFS	N&WWS	N&WFS
Filter 2	11.56	11.56	11.83	12.10
Filter 3	53.40	53.43	57.03	57.73
Filter 4	66.17	66.33	70.67	71.00
Filter 5	70.60	70.93	72.93	74.13
X_{CIE}	64.96	64.99	68.86	69.83
Y_{CIE}	66.17	66.33	70.67	71.00
Z_{CIE}	70.60	70.93	72.93	74.13
x	.322	.321	.324	.325
y	.328	.328	.333	.330
Dominant Wavelength	570	570	573	574
Purity	.073	.073	.096	.098

D. Cook 3A

Chemicals: 3% NaOH, 3% Na_2CO_3, 6 drops Triton X-100

Cook time: 45 minutes

Cook temperature: 160°F

Deinking technique: Sidehill washer

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	62.2	62.7	61.4	62.2	61.1	61.8	64.6	64.8	65.2	65.4	65.3	66.1
	62.2	61.9	61.6	61.6	62.4	57.2	64.8	65.4	65.0	65.2	65.1	65.5
	62.3	62.0	62.0	60.8	60.5	57.9	65.3	64.8	65.2	66.1	66.1	65.3
	61.8	63.0	61.8	60.7	60.8	61.1	64.1	64.2	63.9	65.7	65.9	65.9
	62.5	62.5	57.0	62.1	61.0	62.2	64.3	64.0	64.0	63.9	64.9	65.5
Averages		61.8			60.9			64.6			65.5	

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	11.8	11.9	11.8	11.7	11.4	11.7	12.3	12.3	12.2	12.5	12.5	12.6
Filter 3	55.0	55.6	56.0	55.0	55.0	54.2	58.6	58.4	59.5	59.6	58.9	58.7
Filter 4	68.9	67.7	68.5	67.4	68.2	67.8	73.6	72.5	72.8	73.7	72.9	73.7
Filter 5	72.3	72.2	72.2	71.8	72.3	71.2	75.3	73.7	75.7	75.4	76.3	76.6
X_{CIE}		67.36			66.33			71.10			71.60	
Y_{CIE}		68.37			67.80			72.97			73.43	
Z_{CIE}		72.23			71.77			74.90			76.10	
x		.324			.322			.325			.324	
y		.329			.329			.333			.332	
Dominant Wavelength	574			570			571			574		
Purity	.098			.073			.116			.098		

E. Cook 4A

Chemicals: 4% NaOH, 2% Na_2CO_3

Cook time: 45 minutes

Cook temperature: 190°F

Deinking technique: Sidehill washer

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	61.6	60.8	60.5	60.7	61.6	59.7	64.3	64.2	64.6	65.5	65.1	65.3
	60.9	61.0	60.5	60.7	61.9	62.4	64.5	64.8	65.2	65.4	65.4	65.5
	62.0	61.2	61.4	61.2	61.2	61.0	64.9	64.2	64.5	65.8	65.4	66.2
	62.1	61.2	61.2	61.4	62.4	60.7	64.4	64.4	64.9	65.9	65.0	65.9
	61.8	62.0	61.0	60.9	61.1	58.4	64.3	64.2	64.4	65.6	65.1	65.4
Averages:	61.3			61.0			64.5			65.5		

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	11.6	11.9	11.7	11.6	11.6	11.6	12.2	12.4	12.3	12.5	12.5	12.5
Filter 3	53.6	53.8	53.0	53.5	54.5	54.1	58.6	58.9	58.8	59.0	58.9	58.8
Filter 4	66.9	66.2	66.8	67.3	66.0	66.0	72.6	72.3	71.9	73.6	72.2	72.9
Filter 5	71.2	71.2	70.9	70.7	70.6	70.0	75.0	75.3	74.8	76.6	76.4	77.1
X_{CIE}	65.2			65.6			71.1			71.4		
Y_{CIE}	66.6			66.4			72.3			72.9		
Z_{CIE}	71.1			70.4			75.0			76.7		
x	.321			.324			.326			.323		
y	.328			.328			.331			.330		
Dominant Wavelength	570			574			573			570		
Purity	.073			.098			.096			.073		

F. Cook 5A

Chemicals: 4% NaOH, 2% Na_2CO_3

Cook time: 60 minutes

Cook temperature: 190°F

Deinking technique: Sidehill washer

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	60.6	60.6	60.2	59.3	58.0	56.7	64.4	65.0	65.2	64.7	65.2	64.4
	61.7	61.1	59.9	59.8	62.5	56.3	65.6	65.2	65.4	64.7	64.1	64.3
	62.3	60.9	59.8	58.9	58.8	58.0	65.0	64.5	64.8	64.4	64.5	64.5
	59.1	58.5	60.4	60.0	59.8	56.2	65.4	65.7	65.1	64.3	64.3	64.0
	60.1	60.9	57.0	59.4	60.2	55.7	64.2	63.0	64.3	63.9	64.1	63.7
Averages:		60.2			58.6			64.9			64.7	

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	11.3	11.6	11.6	11.5	11.5	11.3	12.2	12.5	12.6	12.7	12.6	12.5
Filter 3	53.0	51.9	53.3	51.8	52.9	53.5	58.9	57.8	58.2	58.7	58.1	58.6
Filter 4	66.4	65.0	66.1	64.6	67.5	66.7	72.3	70.8	72.6	72.8	72.5	72.8
Filter 5	71.4	70.2	70.9	71.8	69.8	66.8	76.3	76.7	75.8	77.0	76.1	77.1
X_{CIE}		64.2			64.1			70.7			71.1	
Y_{CIE}		65.8			66.3			71.9			72.7	
Z_{CIE}		70.8			69.5			76.3			76.7	
x		.320			.321			.323			.322	
y		.328			.332			.328			.330	
Dominant Wavelength		570			570			574			570	
Purity		.073			.073			.098			.073	

G. Cook 6A (Also named cook 44A)

Chemicals: 4% NaOH, 2% Na_2CO_3, 6 drops Triton X-100

Cook time: 45 minutes

Cook temperature: 190°F

Deinking technique: Flotation cell

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	64.9	64.5	65.5	65.0	65.2	64.4	65.2	65.1	65.2	67.1	67.1	67.1
	65.4	65.0	64.7	65.0	65.3	64.7	65.2	65.6	65.2	67.2	67.2	67.1
	65.9	65.2	65.5	64.6	65.0	65.1	64.7	65.0	65.7	67.5	67.0	67.3
	64.7	64.9	64.9	64.6	64.6	65.2	65.2	65.1	65.3	66.8	67.2	67.4
	64.9	64.4	64.8	64.9	64.7	64.1	64.9	64.5	64.3	67.5	66.9	66.9
Averages:		65.0			64.8			65.1			67.2	

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	12.3	12.4	12.3	12.4	12.4	12.4	12.4	12.5	12.4	12.8	12.8	12.8
Filter 3	55.9	56.0	55.5	55.7	56.1	54.8	57.7	57.2	57.2	58.4	58.5	58.7
Filter 4	68.8	70.2	69.6	68.4	70.1	70.3	72.4	71.5	71.5	73.1	72.5	72.7
Filter 5	75.5	75.8	74.4	76.1	75.1	75.2	75.0	76.3	76.3	78.0	78.0	78.0

	BWS	BFS	N&WWS	N&WFS
X_{CIE}	68.1	67.9	69.7	71.3
Y_{CIE}	69.5	69.6	71.8	72.8
Z_{CIE}	75.2	75.5	75.9	78.0
x	.320	.319	.321	.321
y	.327	.327	.330	.328
Dominant Wavelength	563	563	570	570
Purity	.053	.053	.073	.073

II. Results of deinking runs:

At this point, cook 6A was determined as being the best cook of the six variations that were just outlined. In all following cooks, the variables are as follows:

Cook 100g of printed paper at 6% consistency

Chemicals: 4% NaOH, 2% Na_2CO_3, 6 drops Triton X-100

Cook time: 45 minutes

Cook temperature: 190°F

Deinking technique: Flotation cell

A. Cook 11A Ink=18 mu, high structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	62.1	62.4	62.3	61.3	61.4	61.7	61.3	61.6	61.8	62.9	62.7	63.0
	62.3	61.6	61.8	62.4	62.4	61.6	61.7	61.4	61.7	62.6	62.8	62.1
	62.7	62.8	62.7	61.7	61.1	61.2	61.5	61.4	61.7	62.3	61.9	62.2
	62.9	62.3	61.1	62.0	62.6	62.4	61.5	61.1	61.4	62.6	62.5	62.1
	62.8	62.9	62.9	62.1	61.9	62.5	61.5	61.4	61.9	63.3	63.1	63.0
Means:		62.3			61.9			61.5			62.6	

Color values:

Filter 2	12.0	11.7	11.9	11.6	11.8	11.9	11.6	11.7	11.6	12.0	11.9	11.9
Filter 3	55.6	55.0	53.5	54.9	55.5	53.7	56.5	56.8	56.8	56.9	56.6	56.3
Filter 4	66.7	68.8	69.4	68.2	68.9	67.7	69.4	70.3	69.9	69.8	71.0	70.0
Filter 5	73.3	74.1	72.1	72.8	72.4	72.6	71.6	71.6	71.2	72.5	73.0	73.5
X_{CIE}		66.6			66.3			68.3			68.5	
Y_{CIE}		68.3			68.3			69.9			70.3	
Z_{CIE}		73.2			72.6			71.5			73.0	
x		.320			.320			.326			.323	
y		.328			.330			.333			.332	
Dominant Wavelength	570			570			573			570		
Purity	.073			.073			.096			.073		

B. Cook 22A Ink=17 mu, low structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	59.1	58.7	55.8	59.2	58.8	58.8	57.9	57.8	57.6	61.3	61.4	61.0
	58.8	57.1	58.5	60.9	60.7	60.2	63.5	63.6	63.8	64.2	63.8	64.2
				57.1	57.5	57.2	62.6	61.9	62.1	65.3	65.2	65.4
				57.9	58.1	57.7	62.9	62.5	62.5	64.8	64.6	65.0
							59.9	60.4	60.6	64.8	65.2	65.4
Means:		58.0			58.7			61.3			64.0	

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	11.2	11.2		11.1	11.3	11.6	12.1	11.9	11.1	12.3	12.2	12.3
Filter 3	50.5	50.3		52.5	48.9	49.6	55.3	53.2	56.8	53.9	57.9	56.8
Filter 4	62.4	63.0		62.2	63.5	65.1	69.4	68.6	69.3	70.5	69.8	70.1
Filter 5	68.1	67.9		60.7	67.1	68.1	70.0	74.4	72.9	75.1	72.3	76.3
X_{CIE}		61.6			61.6			66.8			68.5	
Y_{CIE}		62.7			63.6			69.1			70.1	
Z_{CIE}		68.0			65.3			72.4			74.6	
x		.320			.323			.321			.321	
y		.326			.334			.332			.329	
Dominant Wavelength		572			574			570			570	
Purity		.085			.098			.073			.073	

C. Cook 33A Ink=27 mu, high structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	56.9	56.5	55.6	58.8	59.5	58.6	59.0	59.0	58.3	63.5	63.6	63.1
	57.1	56.8	57.4	59.1	58.6	58.8	58.9	59.0	58.9	63.5	63.4	63.8
	57.5	55.7	57.9	57.5	57.8	58.7	58.1	59.1	58.9	63.8	63.1	63.0
	56.1	56.7	57.0	58.3	58.5	58.0	59.5	59.6	59.4	62.8	62.4	63.0
	57.6	56.7	54.0	59.0	58.9	57.8	58.3	57.8	58.2	64.5	64.4	64.4
Means:		56.6			58.5			58.8			63.5	

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	10.9	10.7	10.8	11.2	11.1	11.2	11.2	11.3	11.2	12.4	12.2	11.9
Filter 3	48.1	49.6	49.2	50.2	49.3	49.6	50.7	49.9	51.0	53.8	54.5	54.5
Filter 4	62.4	60.8	62.2	62.4	62.2	61.2	64.5	63.7	63.3	68.2	69.3	68.3
Filter 5	67.2	66.4	66.3	67.3	68.5	68.4	67.8	68.9	69.3	72.7	73.9	73.9
X_{CIE}		59.8			60.9			61.7			66.5	
Y_{CIE}		62.1			61.9			63.8			68.6	
Z_{CIE}		66.6			67.1			68.5			73.5	
x		.317			.321			.318			.319	
y		.329			.326			.329			.329	
Dominant Wavelength		570			574			570			570	
Purity		.073			.098			.073			.073	

D. Cook 55A (Note: Cook 44A = Cook 6A - Previously presented)

Ink=25 mu, low structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	62.4	64.6	63.9	64.6	64.5	64.3	67.0	66.6	66.6	67.7	67.7	67.8
	64.7	64.5	64.5	64.8	65.0	65.2	66.7	66.6	66.3	68.6	68.4	68.7
	64.6	64.7	64.1	64.7	64.6	64.8	66.6	66.5	67.3	68.3	67.9	68.[illegible]
	64.4	64.6	65.4	64.6	64.8	64.6	66.3	65.9	65.8	68.3	68.4	68.[illegible]
	64.3	63.2	63.8	64.8	63.9	64.7	66.6	66.9	66.7	68.0	68.0	68.[illegible]
Means:	64.2			64.7			66.6			68.1		

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	12.4	12.3	12.3	12.3	12.4	12.4	12.6	12.5	12.6	13.1	13.0	12.9
Filter 3	57.4	55.8	57.5	57.5	57.8	57.9	61.5	61.0	61.7	62.0	61.3	62.8
Filter 4	71.3	70.3	69.7	72.0	71.2	70.6	76.2	75.7	75.7	76.3	76.1	76.5
Filter 5	74.9	75.3	74.8	75.0	75.3	75.8	77.0	77.5	77.3	78.9	79.8	79.3

	BWS	BFS	N&WWS	N&WFS
X_{CIE}	69.2	70.2	74.0	74.0
Y_{CIE}	70.4	71.3	75.9	76.3
Z_{CIE}	75.0	75.4	77.3	79.0
x	.322	.324	.326	.323
y	.328	.329	.334	.333
Dominant Wavelength	570	574	571	571
Purity	.073	.098	.116	.116

E. Cook 66A Ink=75 mu, high structure level

Brightness values:

BWS	BFS			N&WWS			N&WFS		
Unobtainable	48.5	49.1	47.3	49.9	49.1	49.4	56.0	56.4	55.8
	51.3	50.5	50.8	52.8	52.2	52.3	57.8	58.3	58.0
	49.8	49.3	49.3	51.5	51.7	51.7	57.2	57.0	57.0
	49.8	50.3	50.3	57.1	56.8	56.2	58.7	58.8	58.0
	49.0	50.2	51.4						
Means:		49.8			52.6			57.4	

Color values:

	BFS			N&WWS			N&WFS		
Filter 2	9.6	9.4	10.2	9.9	10.8	9.4	11.2	11.0	11.0
Filter 3	43.6	41.8	40.6	40.9	44.1	43.4	48.0	49.4	46.1
Filter 4	51.3	51.7	52.2	54.3	60.5	51.4	58.0	60.3	60.0
Filter 5	59.5	56.6	58.8	57.6	61.2	60.1	66.6	68.3	64.8
X_{CIE}		51.7			52.8			58.9	
Y_{CIE}		51.7			55.4			59.4	
Z_{CIE}		58.3			59.6			66.5	
x		.320			.315			.319	
y		.320			.330			.321	
Dominant Wavelength		574			574			574	
Purity		.047			.047			.047	

Note: This sample boiled for a short time.

F. Cook 77A   Ink=75 mu, medium structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	64.6	64.7	65.4	65.3	66.4	65.3	66.2	66.3	66.3	68.1	68.5	67.9
	66.4	65.9	66.7	65.0	64.7	64.3	66.3	65.9	66.1	67.7	68.0	68.2
	64.0	64.4	62.5	63.2	65.5	63.7	65.7	65.8	66.2	67.7	67.6	67.8
	65.9	66.3	66.1	66.7	64.0	66.0	64.9	64.8	64.9	67.8	67.7	68.0
	64.3	64.9	64.7	69.8	64.3	64.4	66.0	66.1	65.9	68.3	67.5	67.7
Means:		65.1			64.9			65.8			67.9	

Color values:

	BWS			BFS			N&WWS			N&WFS		
Filter 2	12.4	12.9	12.5	12.4	12.4	12.3	12.6	12.3	12.6	12.9	13.0	12.9
Filter 3	55.5	56.5	56.3	54.8	56.3	55.0	59.6	60.0	60.1	59.9	60.1	60.4
Filter 4	71.5	69.3	72.1	69.1	70.6	70.3	73.7	74.3	73.6	75.0	74.8	74.6
Filter 5	76.9	75.5	75.8	76.6	76.5	77.1	77.1	77.0	76.3	78.9	79.0	79.1
X_{CIE}		68.7			67.8			72.4			73.0	
Y_{CIE}		71.0			70.0			73.9			74.8	
Z_{CIE}		76.1			76.7			76.8			79.0	
x		.318			.316			.325			.322	
y		.329			.326			.331			.330	
Dominant Wavelength		570			574			571			570	
Purity		.073			.047			.116			.073	

At this point, color values have been obtained for each category, and the variation is minimal in each case. Color determinations will be avoided from now on.

G. Cook 11B Ink=18 mu, high structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	51.4	51.2	50.1	51.0	51.4	50.0	54.9	55.7	55.1	60.1	59.6	59.7
	47.9	49.0	47.7	52.5	52.6	51.6	54.1	59.9	54.8	57.7	58.6	59.3
	50.7	53.2	53.6				55.4	55.6	55.7	58.1	58.5	57.9
							54.0	54.7	54.2	61.2	61.4	60.4
							55.0	54.9	54.4	61.5	61.1	61.3
Means:	50.5			51.5			54.9			59.8		

Note: This sample just started to boil.

H. Cook 22B Ink=17 mu, low structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	57.1	57.6	57.6	57.3	56.0	54.9	57.3	57.7	57.4	62.9	63.1	62.6
	56.2	57.0	56.2	57.0	56.7	56.1	58.4	58.2	57.8	63.1	63.4	63.7
	57.1	56.2	57.0	55.2	55.9	56.0	57.9	58.2	57.5	63.3	63.0	63.5
							56.8	57.4	57.2	63.5	63.0	62.7
							58.5	58.1	58.2	62.8	62.3	62.2
Means:	56.9			56.1			57.8			63.0		

I. Cook 33B   Ink=27 mu, high structure level

Brightness values:

BWS	BFS	N&WWS	N&WFS
unobtainable	57.2 56.8 57.5	57.4 57.8 57.5	64.1 63.6 63.4
	58.1 58.1 56.8	57.1 57.0 57.8	64.0 63.9 64.0
	59.4 59.1 59.8	57.2 57.4 57.7	63.5 62.5 63.5
	60.2 60.0 59.2	58.7 58.9 58.6	63.2 62.8 63.5
		58.4 58.5 58.2	62.6 62.5 62.7
Means:	58.5	57.9	63.3

J. Cook 44B   Ink=27 mu, medium structure level

Brightness values:

BWS	BFS	N&WWS	N&WFS
57.2 57.2 57.8	58.0 57.4 56.8	57.8 58.0 57.9	63.4 63.2 63.5
57.2 56.5 56.6	57.0 55.8 57.6	57.5 57.4 57.5	62.8 63.0 63.3
57.3 56.7 56.6	57.1 57.1 57.0	58.5 58.0 58.4	63.5 63.4 63.2
56.1 57.8 58.2	57.8 57.0 56.6	57.3 57.5 57.4	64.3 64.1 63.1
57.6 58.6 57.9	57.9 57.5 58.5	56.6 56.6 56.4	63.8 63.6 63.3
Means: 57.3	57.3	57.5	63.5

K. Cook 55B Ink=25 mu, low structure level

Brightness values:

BWS			BFS			N&WWS			N&WFS		
66.7	66.5	66.5	66.3	66.9	67.1	65.0	64.8	64.8	67.5	67.4	67.2
66.7	66.1	66.4	66.8	66.7	66.5	65.0	65.3	65.4	67.7	67.4	67.9
66.7	66.2	66.0	66.8	66.6	66.6	65.1	64.8	64.9	68.4	68.5	68.5
66.2	66.6	65.9	65.8	66.6	65.9	64.2	63.9	64.3	68.4	68.6	68.4
66.8	67.0	66.5	66.6	66.0	67.0	65.1	65.5	65.3	67.5	67.6	68.9
Means: 66.5			66.5			64.9			68.0		

L. Cook 66B Ink=75 mu, high structure level

Brightness values:

BWS			BFS			N&WWS			N&WFS		
49.2	46.8	47.6	50.2	51.7	50.7	54.1	54.1	54.3	59.8	60.0	60.3
47.0	47.5	47.7	51.0	50.7	50.6	52.1	52.4	52.4	59.4	59.4	59.4
47.9	46.9	46.0	50.1	49.6	49.9	53.3	53.8	53.3	60.5	60.4	60.5
48.2	47.5	47.6	50.8	50.8	51.9	51.9	52.0	51.9	60.4	60.5	60.3
48.9	46.7	48.8	48.6	49.5	50.0	52.6	52.7	53.0	60.3	59.2	59.7
Means: 47.6			50.4			52.9			60.0		

M. Cook 77B Ink=75 mu, medium structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	62.4	62.1	61.7	62.2	61.8	62.6	63.2	62.7	63.1	68.5	68.1	67.6
	62.2	62.0	62.1	61.9	62.7	62.7	59.5	59.6	59.8	67.9	68.5	68.1
	62.4	62.2	62.7	62.3	61.4	62.4	64.2	64.3	65.1	66.5	66.1	66.3
	61.3	61.2	61.9	62.4	63.2	61.5	64.6	64.3	64.8	64.9	64.3	64.9
	62.1	62.2	62.1	61.1	61.7	62.1	60.6	60.9	62.0	65.5	65.4	64.9
Means:		62.0			62.1			63.3			66.5	

N. Cook 11C Ink=18 mu, high structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	61.3	60.6	60.7	62.6	61.2	62.3	61.1	61.2	61.0	64.1	63.9	64.0
	61.6	61.8	61.7	61.1	60.6	60.7	61.4	61.6	61.1	64.7	64.5	64.8
	60.8	61.2	59.7	61.9	61.9	62.2	61.3	61.3	61.3	64.6	64.6	64.5
	61.4	61.3	62.0	61.6	61.9	62.3	61.1	61.1	60.8	65.1	65.1	64.8
	60.4	61.0	60.3	61.7	62.1	62.5	61.9	62.0	61.8	65.4	65.1	65.4
Means:		61.1			61.8			61.3			64.7	

O. Cook 22C Ink=17 mu, low structure level

Brightness values:

BWS			BFS			N&WWS			N&WFS		
51.8	52.7	51.8	52.3	51.6	51.3	54.6	54.7	54.2	59.5	59.8	59.5
51.2	50.3	51.0	50.8	49.9	51.6	54.1	54.4	53.9	59.5	59.8	59.8
52.7	52.2	52.2	50.1	50.0	49.3	54.5	54.4	54.3	60.6	60.3	60.4
			51.5	52.1	52.7	54.1	54.4	53.8	60.7	60.5	60.3
						56.9	56.8	57.3	59.9	60.1	60.7
Means: 51.7			51.1			54.8			60.1		

P. Cook 33C Ink=27 mu, high structure level

Brightness values:

BWS			BFS			N&WWS			N&WFS		
53.6	53.5	53.7	55.1	54.7	54.9	56.5	56.0	55.5	63.5	63.9	64.0
53.2	52.7	53.1	53.0	53.9	53.3	58.1	58.4	58.4	62.3	63.3	63.4
51.7	51.9	50.7	54.4	53.5	54.4	56.1	56.1	54.8	62.5	62.4	62.6
53.6	54.1	52.7	54.1	55.5	54.8	56.6	56.6	56.1	63.2	62.5	63.2
54.0	54.4	54.9	52.1	54.2	51.7	56.7	58.3	57.5	62.8	63.2	62.3
Means: 53.2			54.0			56.8			63.0		

Q. Cook 44C Ink=27 mu, medium structure level

Brightness values:

BWS			BFS			N&WWS			N&WFS		
56.4	56.3	56.9	56.7	56.6	56.5	58.9	58.5	58.6	63.2	62.7	63.1
57.5	58.3	57.5	58.7	59.2	58.4	57.8	58.4	58.3	62.8	62.5	62.8
58.5	59.1	57.9	58.3	58.3	58.6	58.2	58.0	58.0	62.9	62.7	62.6
58.8	59.9	59.2	59.0	59.3	58.8	58.2	57.9	57.9	63.2	63.5	63.5
59.5	59.8	59.5	59.5	60.2	59.6	58.9	58.4	58.6	63.9	62.8	64.2
Means: 58.3			58.5			58.3			63.1		

R. Cook 55C Ink=25 mu, low structure level

Brightness values:

BWS			BFS			N&WWS			N&WFS		
60.2	60.0	59.3	56.8	56.9	56.8	58.3	58.5	57.3	64.5	64.2	64.2
59.1	58.7	58.7	58.2	57.2	57.1	58.3	59.0	58.6	64.3	64.5	64.6
56.5	57.1	56.4	57.6	59.6	59.1	60.5	61.2	60.9	64.1	64.1	63.6
56.8	58.3	58.3	56.0	56.4	57.0	59.8	60.2	60.5	64.2	63.9	69.0
59.7	58.9	59.5	57.2	57.6	57.4	59.4	59.3	58.7	63.7	64.2	64.5
Means: 58.5			57.4			59.4			64.2		

S. Cook 66C Ink=75 mu, high structure level

Brightness values:

BWS			BFS			N&WWS			N&WFS		
44.7	44.7	44.0	45.1	44.4	44.6	45.8	47.1	46.5	59.6	59.9	60.1
45.8	46.5	44.1	49.2	49.1	48.1	47.6	48.0	47.5	56.3	56.1	55.3
47.0	45.1	45.9	48.8	48.2	48.0	42.6	44.0	41.7	55.5	55.8	56.6
			45.8	46.8	47.0	49.1	49.6	49.2	57.5	57.3	57.0
			45.4	45.1	46.0	49.3	49.3	49.1	57.8	58.0	57.7
Means: 45.3			46.8			47.1			57.4		

T. Cook 77C Ink=75 mu, medium structure level

Brightness values:

BWS			BFS			N&WWS			N&WFS		
52.5	53.4	53.5	55.1	54.9	54.6	56.0	56.3	55.8	61.9	61.5	61.0
55.7	54.5	54.1	54.5	53.8	54.7	56.5	56.8	56.3	60.9	61.3	62.2
55.1	55.3	55.4	52.5	52.7	53.0	57.7	57.8	58.0	62.4	62.5	62.5
55.2	55.6	54.5	55.4	54.8	53.4	57.2	57.6	57.8	62.6	62.8	62.8
			54.5	54.2	55.2	56.8	56.7	57.2	62.7	62.4	62.4
Means: 54.6			54.2			57.0			62.1		

U. Cook 11D Ink=18 mu, high structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	61.5	60.9	62.1	61.8	60.9	61.5	61.6	61.4	61.8	63.2	63.5	63.2
	61.8	62.1	62.0	62.0	62.1	62.1	61.9	62.1	61.7	63.8	63.6	63.6
	61.7	61.6	61.5	61.5	61.7	61.8	62.2	62.3	62.1	62.8	62.5	62.9
	60.6	60.9	61.0	61.9	62.4	62.1	61.5	61.7	61.4	63.9	64.0	64.2
	61.5	61.7	62.1	61.5	61.7	61.9	61.6	61.9	61.8	63.7	63.6	63.6
Means:	61.5			61.8			61.8			63.5		

V. Cook 22D Ink=17 mu, low structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	57.3	57.5	57.4	56.9	56.7	56.9	60.0	59.8	59.7	64.3	64.2	64.1
	58.2	58.1	57.9	57.3	57.4	57.6	59.4	59.6	59.6	63.8	63.6	63.7
	58.3	58.2	58.0	57.8	57.5	57.6	59.1	58.8	59.0	64.0	63.9	63.8
	57.2	57.1	56.9	57.2	57.1	56.9	59.2	58.9	58.7	63.6	63.3	63.7
	57.5	57.8	57.6	56.9	57.1	57.1	59.3	59.5	59.3	63.9	64.3	64.0
Means:	57.7			57.2			59.3			63.9		

Note: Results with very good agreement were obtained in the first three runs of ink 3 (27 mu, high structure level), so it was not repeated a fourth time.

W. Cook 44D Ink=27 mu, medium structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	57.6	57.8	57.5	57.2	57.4	57.2	58.0	58.2	58.3	63.0	63.3	63.2
	57.2	57.4	57.5	57.5	57.6	57.8	58.1	57.9	58.2	62.8	62.6	62.6
	58.1	58.3	58.6	57.5	57.7	57.9	57.7	57.4	57.6	62.9	63.0	63.0
	58.0	58.1	57.9	58.4	58.6	58.7	57.8	57.5	57.7	63.1	63.3	62.9
	58.3	58.4	58.6	58.6	58.6	58.8	58.1	57.9	58.0	62.9	62.8	62.9
Means:		58.0			58.0			57.9			63.0	

X. Cook 55D Ink=25 mu, low structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	64.8	65.1	65.0	65.3	65.5	65.4	65.4	65.8	65.7	67.9	67.8	67.9
	65.1	65.2	65.1	65.6	65.8	65.4	66.2	66.3	66.2	67.7	67.6	67.8
	64.9	65.1	65.2	66.1	66.0	65.8	65.1	65.3	65.2	68.1	68.0	68.0
	65.2	65.4	65.4	65.7	65.8	65.7	64.8	65.2	65.3	67.6	67.8	67.5
	64.9	65.1	65.2	66.1	66.0	66.2	65.9	65.6	65.8	67.8	68.0	67.9
Means:		65.1			65.8			65.6			67.8	

Y. Cook 66D Ink=75 mu, high structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	47.0	47.8	47.9	48.9	49.1	49.2	52.5	52.7	52.8	58.3	58.5	58.4
	48.1	48.3	48.0	48.7	48.8	49.1	52.1	52.4	52.3	58.6	58.8	58.7
	47.6	47.3	47.5	49.3	49.5	49.5	53.1	53.3	53.0	58.0	58.2	57.9
	48.1	48.4	48.2	48.8	48.7	49.0	52.7	52.9	52.6	57.8	58.0	58.1
	47.9	48.1	48.0	49.2	49.1	49.0	52.6	52.4	52.3	58.3	58.5	58.4
Means:		47.9			49.1			52.6			58.3	

Z. Cook 77D Ink=75 mu, medium structure level

Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	63.4	63.7	63.2	62.9	62.7	62.5	64.0	64.2	64.3	67.1	67.3	67.6
	64.1	64.3	63.9	63.1	63.3	63.0	65.1	65.4	64.9	67.4	67.8	67.6
	64.2	64.6	64.1	63.4	63.6	63.1	63.9	64.2	63.8	67.0	66.9	67.2
	63.5	63.3	63.3	62.8	63.0	62.7	64.4	64.6	64.1	67.3	67.5	67.6
	63.7	63.9	64.0	63.1	62.9	63.0	64.6	64.0	63.8	66.8	66.9	67.0
Means:		63.8			63.0			64.4			67.3	

III. Optical properties of original, unprinted paper:

A. Optical properties of sheets of the original paper.

Brightness values: 65.9, 65.8, 65.8, 65.6, 65.6, 65.7, 65.9, 65.8, 65.6, 65.5, 65.4, 65.3, 65.4, 65.3, 65.3, 65.7, 65.3, 64.9.

Average brightness: 65.54

Color values:

er 2: 12.4, 12.5, 12.5, 12.5, 12.4, 12.4, 12.6, 12.5, 12.4, 12.5, 12.4, 12.4

er 3: 65.3, 65.4, 65.4, 65.3, 65.4, 65.5, 65.4, 65.3, 65.3, 65.4, 65.5, 65.3

er 4: 79.7, 79.6, 79.6, 79.7, 79.6, 79.8, 80.0, 80.0, 79.9, 79.9, 79.7, 79.9

er 5: 76.8, 76.9, 76.5, 76.9, 76.4, 76.2, 76.5, 76.4, 76.9, 76.3, 76.6, 76.6

X_{CIE}: 77.83

Y_{CIE}: 79.78

Z_{CIE}: 76.58

x : .332

y : .341

Dominant wavelength: 562

Purity: .258

B. Optical properties of original paper beaten up in Waring Blendor and reformed as Noble and Wood handsheets:

Brightness values: 65.6, 65.1, 65.2, 65.5, 65.3, 65.5, 65.3, 65.8, 65.4.

Average brightness value: 65.4

Filter 2:	12.4	12.5	12.4	12.4	12.4
Filter 3:	64.7	65.1	64.9	64.8	64.5
Filter 4:	78.7	78.9	78.8	76.8	78.5
Filter 5:	76.3	76.2	76.0	75.8	76.0

X_{CIE}: 77.8 Y_{CIE}: 78.3 Z_{CIE}: 76.1

x: .335 y: .337

Dominant wavelength: 578 Purity: .118

C. Optical properties of original ~~properties~~ paper that is unprinted, but still run through the entire deinking process as outlined at the beginning of section II in this appendix:

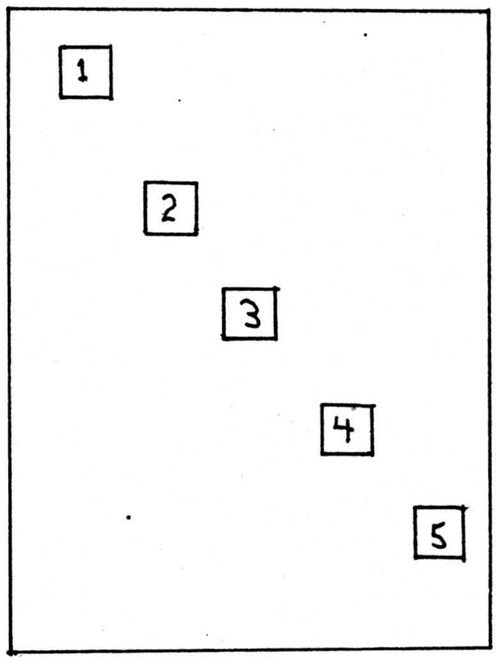
Brightness values:

	BWS			BFS			N&WWS			N&WFS		
	71.3	71.6	70.7	72.0	71.6	71.7	71.0	71.0	70.7	71.6	71.2	71.8
	71.8	71.8	71.9	72.0	71.9	72.0	70.9	70.6	70.6	71.8	71.6	71.4
	71.1	71.8	71.6	72.0	71.9	71.8	71.0	71.0	70.8	71.3	71.2	71.1
	70.7	70.6	70.9	70.4	70.8	70.8	71.3	71.2	71.3	71.1	71.2	71.4
	71.1	70.9	71.9	72.0	71.7	72.1	70.3	70.4	70.3	70.9	70.5	70.9
Means:		71.3			71.6			70.8			71.3	

IV. Densitometer readings to determine ink coverage density:

All densitometer readings were made on a Macbeth Quanta Log densitometer. It was calibrated with a Macbeth Reflection Check Plaque. Standardization settings were .08 and 1.83.

The paper was printed with five one-inch squares placed diagonally on it. This arrangement made it possible to maintain even ink coverage across the width of the sheet. The five positions were recorded according to the following grid:



A. Ink=18 mu, high structure level

	1	2	3	4	5
	1.36	1.31	1.33	1.32	1.34
	1.34	1.31	1.28	1.32	1.33
	1.33	1.28	1.30	1.29	1.34
	1.31	1.27	1.30	1.33	1.34
	1.30	1.22	1.32	1.29	1.34
	1.33	1.30	1.31	1.30	1.34
	1.33	1.33	1.33	1.32	1.33
	1.31	1.29	1.30	1.30	1.34
	1.35	1.33	1.33	1.34	1.35
	1.30	1.28	1.30	1.31	1.33
	1.33	1.34	1.32	1.32	1.34
	1.33	1.25	1.30	1.33	1.34
	1.33	1.33	1.32	1.34	1.34
	1.35	1.32	1.29	1.34	1.33
	1.36	1.35	1.32	1.34	1.37
	1.33	1.31	1.32	1.32	1.33
	1.34	1.34	1.34	1.33	1.35
	1.34	1.33	1.33	1.32	1.37
	1.37	1.36	1.33	1.34	1.36
Mean:	1.33	1.31	1.31	1.32	1.34
Standard deviation:	.0195	.0358	.0164	.0166	.0124

B. Ink=17 mu, low structure level

	1	2	3	4	5
	1.30	1.17	1.24	1.26	1.30
	1.27	1.24	1.26	1.25	1.28
	1.33	1.31	1.31	1.30	1.31
	1.30	1.20	1.27	1.26	1.30
	1.29	1.25	1.26	1.27	1.32
	1.29	1.26	1.27	1.29	1.31
	1.29	1.26	1.29	1.27	1.30
	1.30	1.26	1.28	1.26	1.30
	1.30	1.27	1.29	1.28	1.32
	1.30	1.25	1.29	1.29	1.31
	1.28	1.22	1.23	1.23	1.30
	1.26	1.18	1.24	1.23	1.27
	1.27	1.17	1.19	1.24	1.29
	1.32	1.27	1.29	1.30	1.32
	1.21	1.10	1.20	1.24	1.28
	1.31	1.25	1.24	1.25	1.28
	1.30	1.26	1.27	1.27	1.27
	1.33	1.31	1.30	1.31	1.31
	1.32	1.27	1.30	1.31	1.31
Means:	1.29	1.24	1.26	1.27	1.30
Standard deviation:	.0279	.0523	.0336	.0258	.0163

C. Ink=27 mu, high structure level

	1	2	3	4	5
	1.28	1.25	1.32	1.37	1.38
	1.33	1.22	1.31	1.32	1.34
	1.31	1.29	1.32	1.31	1.34
	1.34	1.26	1.34	1.32	1.36
	1.32	1.27	1.31	1.32	1.36
	1.35	1.33	1.32	1.34	1.34
	1.32	1.30	1.33	1.31	1.34
	1.34	1.31	1.32	1.34	1.36
	1.34	1.25	1.32	1.32	1.36
	1.33	1.30	1.30	1.33	1.35
	1.34	1.28	1.33	1.33	1.36
	1.31	1.33	1.36	1.32	1.35
	1.34	1.33	1.34	1.35	1.35
	1.32	1.32	1.32	1.33	1.35
	1.35	1.35	1.34	1.36	1.35
	1.30	1.33	1.33	1.34	1.35
	1.31	1.34	1.34	1.33	1.36
	1.31	1.36	1.36	1.35	1.37
	1.31	1.34	1.35	1.36	1.36
Means:	1.32	1.30	1.33	1.33	1.35
Standard deviations:	.0241	.0342	.0165	.0174	.0108

D. Ink=27 mu, medium structure level

	1	2	3	4	5
	1.28	1.28	1.26	1.22	1.30
	1.11	1.07	1.08	1.09	1.26
	1.25	1.17	1.06	1.13	1.23
	1.27	1.19	1.20	1.17	1.24
	1.24	1.20	1.21	1.14	1.24
	1.29	1.27	1.25	1.23	1.27
	1.30	1.23	1.23	1.19	1.26
	1.33	1.08	1.28	1.31	1.30
	1.21	1.12	1.20	1.21	1.24
	1.23	1.14	1.16	1.23	1.22
	1.30	1.27	1.27	1.29	1.29
	1.30	1.31	1.32	1.32	1.33
	1.30	1.29	1.28	1.29	1.30
	1.27	1.20	1.20	1.24	1.23
	1.21	1.09	1.14	1.22	1.24
	1.27	1.20	1.22	1.25	1.28
	1.31	1.22	1.22	1.26	1.27
	1.30	1.23	1.24	1.26	1.26
Means:	1.27	1.20	1.21	1.23	1.26
Standard deviations:	.0517	.0739	.0678	.0628	.0305

E. Ink=25 mu, low structure level

	1	2	3	4	5
	1.26	1.28	1.26	1.25	1.27
	1.28	1.23	1.25	1.18	1.27
	1.30	1.19	1.19	1.12	1.24
	1.32	1.24	1.24	1.19	1.27
	1.29	1.19	1.23	1.13	1.28
	1.26	1.21	1.24	1.20	1.26
	1.30	1.27	1.26	1.20	1.28
	1.33	1.30	1.28	1.21	1.25
	1.33	1.30	1.29	1.25	1.30
	1.32	1.30	1.26	1.19	1.29
	1.33	1.29	1.32	1.23	1.31
	1.33	1.31	1.30	1.28	1.30
	1.34	1.34	1.35	1.31	1.29
	1.32	1.34	1.33	1.33	1.27
	1.30	1.15	1.15	1.10	1.26
	1.29	1.17	1.19	1.13	1.23
	1.29	1.21	1.23	1.15	1.24
Means:	1.31	1.25	1.26	1.20	1.27
Standard deviations:	.0248	.0691	.0524	.0664	.0229

F. Ink=75 mu, high structure level

	1	2	3	4	5
	1.32	1.28	1.27	1.30	1.30
	1.27	1.23	1.25	1.25	1.27
	1.34	1.27	1.31	1.29	1.32
	1.32	1.21	1.24	1.25	1.26
	1.33	1.27	1.29	1.32	1.30
	1.32	1.26	1.27	1.27	1.28
	1.31	1.24	1.27	1.25	1.27
	1.34	1.30	1.32	1.26	1.28
	1.31	1.26	1.26	1.25	1.27
	1.31	1.25	1.25	1.25	1.27
	1.22	1.21	1.29	1.29	1.28
	1.24	1.23	1.24	1.27	1.30
	1.25	1.23	1.25	1.25	1.28
	1.24	1.24	1.25	1.25	1.31
	1.29	1.21	1.25	1.28	1.27
	1.27	1.20	1.25	1.26	1.27
	1.34	1.31	1.31	1.30	1.32
Means:	1.30	1.25	1.27	1.27	1.29
Standard deviations:	.0394	.0339	.0260	.0226	.0191

G. Ink=75 mu, medium structure level

	1	2	3	4	5
	1.29	1.23	1.23	1.20	1.23
	1.27	1.21	1.15	1.17	1.21
	1.28	1.11	1.20	1.18	1.23
	1.28	1.19	1.17	1.17	1.22
	1.27	1.20	1.20	1.17	1.21
	1.31	1.26	1.27	1.25	1.27
	1.29	1.22	1.19	1.19	1.24
	1.25	1.21	1.19	1.20	1.23
	1.29	1.23	1.25	1.22	1.25
	1.28	1.24	1.21	1.20	1.23
	1.29	1.22	1.20	1.21	1.23
	1.27	1.23	1.21	1.21	1.23
	1.32	1.26	1.25	1.25	1.25
	1.27	1.24	1.23	1.21	1.24
	1.32	1.27	1.26	1.24	1.27
	1.35	1.29	1.29	1.26	1.29
	1.34	1.27	1.29	1.27	1.29
Means:	1.29	1.23	1.22	1.21	1.24
Standard deviations:	.0270	.0408	.0406	.0323	.0246

V. Sample of original paper with printing applied

Judge Clemens, who time and again had wrecked or crippled his fortune
devices more or less unusual, now adopted the one unfailing method of
ieving disaster. He endorsed a large note for a man of good repute, and
payment of it swept him clean: home, property, everything vanished. A
Louis cousin took over the home and agreed to let the family occupy it on
[redacted] a small interest. But disaster overtook them again; for Judge
[redacted]d.

[redacted]y Sam was fairly broken down, remorse, which had always dealt with
[redacted]ngly, laid a heavy hand on him now. Wildness, disobedience, in-
[redacted]to his father's wishes, all were remembered; a hundred things, in
[redacted]trifling, became ghastly and heartwringing in the knowledge that
y could never be undone. Seeing his grief, his mother took him by the hand
led him into the room where his father lay.

"It's all right, Sammy," she said. "What's done is done and it does not
ter to him any more; but here by the side of him now I want you to promise
-"

He turned, his eyes streaming with tears, and flung himself into her arms.

"I will prom[redacted]g," he sobbed, "if you won't make me go to school!"

"No, Sammy; [redacted]t go to school any more. Only promise me to be a
ter boy. Prom[redacted] break my heart."

So he promis[redacted]e a faithful and industrious man, and upright, like
father.

A year and p[redacted] of another passed along before Mrs. Clemens and
son Samuel had another sober talk, and, realizing that the printing trade
ered opportunity for acquiring further education as well as a livelihood,
y agreed that he should be apprenticed to a printer. The apprentice terms
e not over-liberal. They were the usual thing for the time: board and
thes - "more board than clothes, and not much of either."

When he had been there little more than a year Sam had become office
orite and chief standby. Whate[redacted]ed intelligence and care and imag-
tion was given to Sam Clemens. [redacted]set type accurately and rapidly;
could wash up the forms a good [redacted]r than the printer himself; and
could run the job-press to the [redacted]nnie Laurie" or "Along the Beach
Rockaway," without missing a s[redacted]sing a finger. It is not believed
t Sam had any writing ambition[redacted]n. His chief desire was to be an
round journeyman printer.

After he had finished his apprenticeship he found a job in the composing
n of the St. Louis Evening News. He remained on the paper only long enough
earn money with which to see the world. The world was New York City, where
Crystal Palace Fair was then going on. The railway had been completed by
s time, but he had not traveled on it. It had not many comforts; several
s and nights were required for the New York t[redacted] was a wonderful
beautiful experience.

On the whole there was not much inducement [redacted]n New York after he
satisfied himself with its wonders. He linge[redacted]er, through the hot
ths of 1853 and presently went on to Philadel[redacted]he found work
bbing" on a daily paper, the Inquirer. Days [redacted]s when there was no
ant place for him to fill he visited historic sites, the art-galleries,
the libraries.

In January, when the days were dark he grew depressed and made a trip to
hington to see the sights of the capital. His stay was comparatively brief,
he did not work there. He returned to Philadelphia, working for a time
the Ledger and North American.

It was late in the summer of 1854, when he finally set out [redacted]
n to the West. His Wanderjahr had lasted nearly fifteen month[redacted]

After a short visit with his family he decided to go back t[redacted]i,
h would be on the way either to New York or New Orleans. He [redacted]rk

VI. Use of the Voith laboratory flotation deinking cell:

This flotation cell requires close attention to perform adequately. It has a 17 liter capacity, so when the 100 grams of cooked stock is diluted to this total volume, it is at a consistency of 0.6 percent. Commercial flotation cells are staged so that primary cell rejects go to a secondary cell. This design is impractical here, though, so all stock and ink that is not removed as froth circles back into the cell and passes through the system again. The cell is operated for 12 minutes. Bubble size control is crucial. Oversized bubbles tend to cause all the fibers to float and be rejected so that only fines and filler is retained. Bubble size must be kept small then. As the stock recycles back into the cell, it passes through a small reservoir with a pump at the bottom. It is crucial to maintain a water level of .25 to .50 inch above the bottom of this reservoir. If this level is not maintained, air is entrained by the pump, and grossly oversized bubbles form.

Since the cell is so small, strong surface currents are not formed as with commercial flotation cells. The ink laden froth tends to collect just at the water surface and requires constant attention to keep this froth moving toward the rejection gate where it is pushed away as rejects.

VII. Use of the Technidyne Corporation Brightness Tester and Colorimeter: This device has several filters which are readily selected by spinning a filter wheel. Filter one is used for brightness determinations. This tester is standardized with standard chips just like all other brightness meters.

Filters two through five are used for color determination. The values from filters two and three are added to give a parameter referred to as "X_{CIE}." The value from filter four is taken directly as value "Y_{CIE}." The value from filter five is taken directly as value "Z_{CIE}." These CIE values are then manipulated to give two more parameters.

$$x = \frac{X_{CIE}}{X_{CIE} + Y_{CIE} + Z_{CIE}} \qquad y = \frac{Y_{CIE}}{X_{CIE} + Y_{CIE} + Z_{CIE}}$$

x and y are referred to as chromaticity coordinates. These values are plotted on a standard chromaticity diagram. The final color is reported as a combination of two numbers. One of these numbers, the dominant wavelength, is obtained by drawing a line from the center of the diagram through point (x, y). Where this line intersects the outside of the diagram is the dominant wavelength, expressed in nanometers. The other number used in describing a color is purity. Purity is obtained by measuring the distance from the diagram center to the point (x, y), and dividing this distance by the distance from the diagram center to the outside of the diagram. Purity is typically reported as percent or as its decimal equivalent.