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THE EFFECTS OF TEMPERATURE AND pH
IN FLOTATION DEINKING OF ULTRAVIOLET-CURED INKS

BY

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A Thesis submitted
in partial fulfillment of
the course requirements for
The Bachelor of Science Degree

Western Michigan University

Kalamazoo, Michigan

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ABSTRACT

Since 1974, the use of ultraviolet-cured inks and coatings has become popular with the printing industry. Unfortunately for the deinking industry, removal of these inks is difficult using conventional methods in the U.S. Theory and laboratory work suggests these special inks may be removed using the flotation process.

It was discovered that the optimum flotation cell temperature for UV-cured inks is not significantly different than the optimum temperature for normal emulsifiable inks. However, optimum cell pH was found to be different between the two inks, and most effective at low pH for UV-cured ink.

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INTRODUCTION AND STATEMENT OF PROBLEM

Since 1974, inks which are nearly instantaneously cured by ultraviolet radiation have become very popular to the coating and printing industry. There are very good reasons why UV-cured inks are attractive to printers. However, the chemistry of these inks makes their eventual removal from a paper or paperboard substrate a difficult, if not impossible task using conventional deinking methods. Deinking by flotation is a possible solution. In previous research, the optimum HLB factor of an emulsifier for UV-cured inks was determined to be 12.5-15.0.(28) The purpose of this project is to continue on this area, and examine the effect of pH and temperature in the flotation cell for the deinking of UV-cured inks.

REVIEW OF LITERATURE

Ultraviolet-Cured Inks

Patents for UV-curable coatings and inks date back to 1946. However, the technology and equipment did not develop until around 1974 (1). Partly responsible for this development was the sharp increase in fuel costs to operate conventional ink drying equipment (2).

The advantages of UV-cured inks are as follows:(3)

- 1) There is no solvent effluent from the polymerization, therefore expensive volatile-handling blowers and afterburners are not necessary.
- 2) Because the surface of the ink film is instantly sealed by the UV radiation, improved print quality at higher printing speeds is possible.
- 3) Drying is immediate, so wet trapping between stages of a multicolor press is eliminated.
- 4) Anti-offset powders are not needed in sheet-fed operations.
- 5) The inks are solventless, so they do not dry up and force cleaning of press equipment.
- 6) UV-cured inks have a longer shelf life, when shielded from UV radiation.
- 7) The UV ovens are less expensive and require less space than thermal ovens. UV ovens can result in as much as 90% energy savings.
- 8) Because the substrate is not exposed to high temperatures during drying, vinyl sheets, mylar films or plastics can be

printed without danger of heat distortion.

A free radical photopolymerization and/or a photocrosslinking reaction is applied in most of the UV-cured inks. The basic components of a UV-curing ink are 1) reactive monomers, 2) prepolymers and/or polymers, 3) photoinitiators, and 4) special additives (1,3,5).

To facilitate high crosslinking speeds, multifunctional monomers, offering many unsaturated, reactive sites are generally used. Also, the high molecular weight of polyfunctional monomers contributes to low volatility and odor, and reduced affect on rubber rolls and blankets. Monomers most used in UV printing inks are acrylates and methacrylates. Also used are vinyl ethers and itaconates (3).

Inks can contain prepolymeric or oligomeric compounds to contribute viscosity, tack, and wetting ability. Polymers can also improve gloss, rub resistance, and hardness. However, these polymers must all be compatible to the UV-curable system.

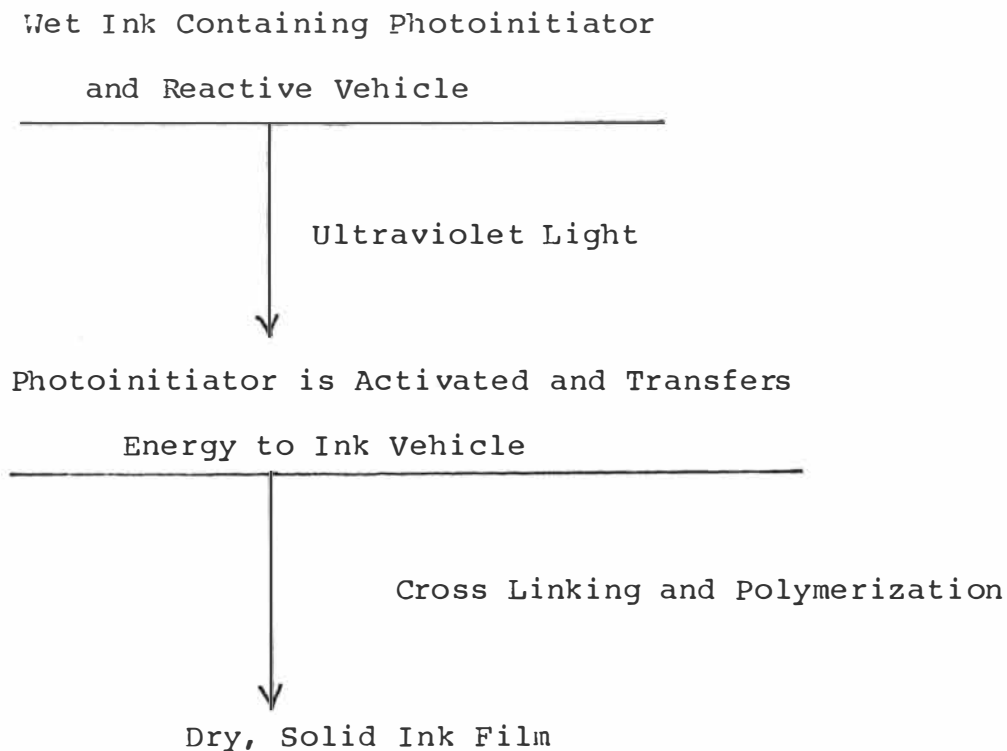
The key to the UV-curable ink is the photoinitiator. There are several classes of reactive chemicals which can be used. Widely applied are aromatic and aliphatic ketones such as benzophenone and acetophenone derivatives. Acyloins and acyloin ethers such as benzoin and bezoin ethers are used most often in very light-colored inks, since they do not discolor severely after irradiation. The photoreactivity of halogens such as chlorine and bromine is well-known, however these are usually blended with other photoinitiators. They increase reaction

speed but can cause odor problems. Photoinitiators are usually a small percentage of the overall ink formulation (1).

UV inks can also contain special additives to modify slip, scratch resistance, flow, tack, viscosity, rub resistance and misting. Additives are often similar to compounds used in conventional inks, however, they must be compatible to the UV curing system (5).

The optimum drying mechanism is one of sealing/setting the surface of the ink with UV light and then applying a post UV oxidative curing to complete crosslinking (3).

Figure 1: Sequence of Curing Steps of UV-Cured Inks



To prepare a UV-curable formulation, the unsaturated polymer is dissolved in a multifunctional monomer along with the photoinitiator. The monomer acts as a crosslinking agent, and due to its lower viscosity, it is also the reactive solvent, becoming part of the polymer system after curing. Compounds to modify polymer properties may also be present. Under the UV light, the photoinitiator is decomposed to generate free radicals which start the polymerization process. The components are converted to a solid, crosslinked polymer film almost instantaneously.

These UV generated polymers prove to be very difficult to break up and disperse. The major obstacle is that polymers formed are not generally alkali-swellable (3,22). High pH in the repulping stage of deinking is the standard practice for saponification of conventional inks. Repulping of UV-cured ink leaves particles of 50-100 μ , much too large to be removed by washing techniques. Photographs of two prepared slides can be seen in appendix I. These are slides of a normal offset ink and of a UV-cured ink, both treated identically with the repulping method used in this thesis. The large, 250 μ , particles of the UV-cured ink are easily seen.

One solution to the problem of UV-cured inks would be for ink makers to incorporate alkali-swellable prepolymers and monomers into the ink. Another solution is to apply flotation to remove these larger ink particles from the repulped suspension. Calculations using theoretical data have shown

flotation capable of removing flat particles up to .3 cm (3).

Flotation

It is not the purpose of this paper to go into lengthy discussions on the positive and negative aspects of deinking by flotation. Simply stated, flotation may be the best/only method of removing the 50-100% non-dispersible particles of UV-cured ink from pulp fiber suspensions.

Flotation technology was developed almost entirely by the metallurgical industry, which bubbled air through ore suspensions to remove valuable components. The first commercial deinking cell was started in 1950, by J.W. Jelks. Although cells differ in design specifics, a common principle of all the cells is the introduction of air bubbles into the stock. By modifying the surfaces of the ink particle and bubbles chemically, the ink will adhere more readily to the air bubbles and be floated to the surface of the cell, where the foam can be skimmed off and concentrated further.

Both washing and flotation deinking begin with a repulping operation, where the reclaimed paper or paperboard is dispersed into a fibrous slurry using chemical, mechanical and thermal energy to detach the ink from the fibers. Sodium hydroxide, sodium silicate, sodium peroxide and detergents are commonly used to saponify the ink vehicle, and with the addition of shear and higher temperatures, the pigments of the ink are dispersed and emulsified. (This saponification and dispersion does not occur with UV-cured inks.)

Conventional deinking uses water displacement and washing

on screens and presses. This makes the system highly sensitive to the particle size.

Surfactants (surface active agents) used in the deinking are commonly described by the HLB value. Surfactants contain both polar hydrophilic (water loving) functional groups and lipophilic (oil loving) groups. The HLB factor was developed by W.C. Griffith in 1948 (21). HLB is a measure of the weight ratio of these two kinds of groups in the surfactant. Previous research has shown that for UV-cured inks to be floated, the optimum HLB for the surfactant is 12.5 or 15.0, suggesting the surfactant acts as an emulsifier/detergent/solubilizer (28).

Flotation Theory

There are three phases present in flotation. They are: 1) liquid - the continuous water phase of the suspension, 2) solid - the detached ink particles (if the cell is operated properly the paper fibers are involved minimally), and 3) gas - the air bubbles. Air is introduced by injection of compressed air at the bottom of the cell, or is drawn into the low pressure vortex of the agitator(s).

Solid particles vary in their ability to attach to the air bubble. Chemicals called collectors are added to the flotation system to stimulate this attachment. The verticle force applied to the particle is: (11,12)

$$\gamma_{a/w} \cos \theta (\text{perimeter of particle}) = V(d_p - d_w)g$$

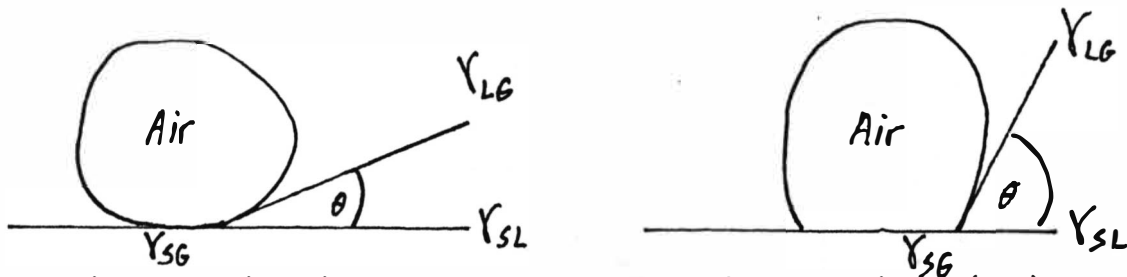
where $\gamma_{a/w}$ = surface tension of water phase

θ = contact angle of water and particle phase

V =particle volume d =density of particle and water

In a three phase system, the air, water and particle meet to form a contact angle at equilibrium (11,12,13).

Figure 2: Contact Angle in a Three Phase System



Interfacial tension is expressed by Young's equation: (20)

$$\gamma_{sg} = \gamma_{sl} + \gamma_{lg} (\cos \theta)$$

If the contact angle of the system is low, the liquid wets the surface easily and bubble attachment to the particle is difficult. Collectors therefore reduce the Helmholtz free energy of the solid-gas interface and increase the free energy of the solid-liquid interface, decreasing wettability and increasing contact angle. The result is an ink particle which desires to orient itself to an air bubble and not the liquid phase. Contact angles above 50 to 70 degrees are required for satisfactory flotation (20).

Collectors are commonly added as soluble soaps. Ions, namely calcium, precipitate the soaps so that they are able to work on the ink surface. These soaps are usually added in excess, so that some of the soap will remain soluble. This portion of the soluble soap acts as a foam stabilizer or foamer.

Foamers work by establishing like charges around the bubble which help make it stable in the water phase and help repel adjoining bubbles at the surface, stabilizing the foam (15). Pine oil is commonly added as a foamer.

The water phase can be altered by modifying the electrolyte properties with pH and temperature adjustment. Temperature is also important in the properties of the surfactant. These chemicals work better in ion form than when they start to agglomerate and form micelles at the clouding point (12,13).

Flotation Factors

The objective of the modern flotation deinking process should be to remove enough ink from the reclaimed paper/paperboard to generate pulp of a specified cleanliness and brightness. This is accomplished by adjusting the chemical levels and mechanical/thermal treatment in the repulper and flotation cell. In order to intelligently control these factors, knowledge of the incoming waste paper must be thorough. The deinking mechanism must respond to changes in production rate, fiber levels, ink coverage and percentage, and ink type. Collector levels in the flotation cell are extremely critical as low levels will lead to ink carryover and low brightness, while high levels easily lead to felt blinding during dewatering on the paper machine (7). Detergents used in the cell to promote fiber wetting and foaming, and to keep scum off the walls, can in excess lead to fiber losses and in closed water systems can build up and cause contamination due to emulsified ink (7).

Temperature and duration of pulping are variables which must be controlled for even pulp quality. Flotation chemicals are added after repulping and allowed to act for a specified dwell time in storage/surge tanks. This dwell time can be varied.

Variables of the flotation cell are as follows: 1) water hardness, 2) pH, 3) consistency, 4) particle size, 5) bubble size, 6) impeller speed, 7) quantity of air added, 8) dwell time in the cell, and 9) temperature in the cell. Deinking efficiency is controlled by manipulating these factors. However, many of the variables are interrelated, and effecting a change in one may cause dramatic changes in one or more of the others.

Water Hardness

As expected, calcium ions are needed to precipitate the collectors/soaps. Ineffective flotation occurs when insufficient ions are present (0-75 ppm). However, excess calcium does not improve flotation. At extremely high levels when all of the soap is precipitated, foam levels will be inhibited. Tap water is ideal, as it usually contains the required amount of hardness ions and does not require chemical treatment (6).

pH

Operation of the cell is usually kept between pH 8 and 10 for normal emulsified ink. Very complex reactions and severe

conditions are reported at low and high pH. Bubble size, fiber carryover, water tension, ink removal, and froth formation can tumble reasonably out of control when pH is altered even slightly into these regions (6). This is one of the variables to be examined in this project and will be discussed fully later.

Consistency

Consistency in the cell is generally kept between 0.5 and 1.2 percent (7,8,17,18). At lower consistencies, fibers are carried into the foam and removed. At higher consistencies, fibers are caught up in the dirt and ink and also carried off in the effluent stream.

Particle Size

Research has shown that flotation becomes ineffective for particle sizes below 5 microns (28). As stated earlier, the flotation process, in theory, is capable of removing particles much larger than the largest size ink particle (3).

Bubble Size and Air Quantity

These are perhaps the most important variables in the cell and yet the most uncontrolled. Bubble size should be small, as small bubbles possess the highest surface area, yet large enough to be stable and provide large buoyant forces. Bubble size has been related to pH, temperature, and the quantity of air

introduced into the cell (6,7). New designs in flotation cells seem to revolve around restructuring of the air delivery and air dispersant systems.

Impeller Speed

Increased brightness of pulp from the flotation cell has been related to increased turbulence due to the impeller (6). The maximum in a laboratory cell was found to be 2500 rpm, above which no brightness increase resulted.

Flotation Time

The dwell time for stock in the cell can also be critical. Insufficient time will not allow for the maximum ink removal. Allowing too much time will cause extra fiber loss as the fibers are flotated and removed with the foam. Normal times of eight to twelve minutes are used (6,7).

Temperature

Temperature is related to bubble size and surface tension of the water. In studies by Raimondo (6) the brightness was found to increase with temperature up to 60°C (when the polyvinylchloride of the lab cell became plastic and pliable). A curious 'blip' occurred at approximately 42-45°C, when the brightness increased sharply and then fell again. Possible explanations are a maximum effect of reducing surface tension and increasing liberated gas in solution. Also possible are the

melting of paper and ink compounds at this temperature. This is the other experimental variable to be examined in this project. It would be interesting to duplicate this 'blip'.

EXPERIMENTAL SECTIONObjectives

It is hoped to demonstrate that an optimum pH exists for the flotation deinking of UV-cured inks. It will be interesting to see if the pH range differs with the ink system deinked (conventional inks vs. UV-cured inks).

It is also hoped to demonstrate that an optimum cell temperature exists for UV-cured inks. The temperature blip reported by Raimondo (6) would be an interesting phenomenon to duplicate. Perhaps, it would result in an extra 2-3 points of brightness with a minimum of extra energy.

Experimental Design

It was desired to investigate the effect of cell pH and cell temperature. A total of twelve flotation runs were conducted (see appendix II). In runs 1 through 6, the pH was held constant at 8.0 while the temperature was varied (approximately 20,30,40,45,50,60 °C). In runs 7 through 12, the temperature was held at 40°C, while the pH was varied (approx. 4,6,8,9,10,12).

In order to use the duplicated condition (pH=8,temp=40°C), air flow was increased between the temperature constant runs and the pH constant runs.

Experimental Procedure

Equipment and Modifications

The Voith Laboratory Flotation Cell was used for the flotation runs. Essentially, the cell consists of a 12-liter plexiglas box. A blade impeller is centrally located in the bottom of the cell. It is driven by a shaft connected to a motor unit on the top of the cell unit. An effluent removal chamber is located near the top of the cell. This chamber has the capability of removing the foam layer on the surface and also recycling acceptable stock. A small motor-driven paddlewheel enhances removal of the surface foam. A hand-valve is used to control the rate of recycle flow, which reenters the cell through the impeller cavity at the bottom of the cell. There are two adjustable dams, one controls the liquid entering the effluent chamber, the other controls the liquid level in the effluent chamber. A small diameter air hose runs from the impeller cavity at the bottom of the cell to a screw valve located at the top of the cell.

The casing which runs from the impeller shroud to the bearings at the top, and encloses the impeller shaft, had been cut approximately three inches from the top. This allowed unrestricted air flow through the casing and directly into the impeller cavity. Attempts at flotation with this condition resulted in uncontrolled foam production, with froth building six to ten inches above the surface of the stock and cascading

over the sides of the cell.

A plastic collar was installed which attached to both the shaft casing (small diameter) and bearing casting (larger diameter). This collar was secured with black tape. A very small amount of air still entered the impeller cavity, probably through the shaft bearings, but this air was negligible.

The air tubing which runs from the impeller cavity to the air flow valve was replaced. A crude, but effective air velocity meter was constructed with plastic tubing, a pinch clamp (simulated orifice), and inclined manometer. Since air flow was not one of the variables of interest it was only necessary to keep air flow constant throughout the runs.

Two compressed air jets were installed at the rear of the cell. These were pointed at the surface of the liquid and provided sufficient force to overcome the tendency of the foam to remain stagnant at the rear of the cell.

Photographs of the cell and air flow device are presented in appendix III.

Ultraviolet-Cured Ink

An industrial source of UV-cured ink was located in the Kalamazoo area.

Chemicals Used

The only flotation chemical used was the surfactant. It was Lipal 9N, manufactured by PVO International. This

surfactant has an HLB of 15.0, and was added at .5% of dry fiber weight.

Sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH) were used for pH adjustment.

Procedure

A 56.50 gram sample of inked stock was slushed with 2500 ml of cold tap water in a 3000 ml Waring blender for 2.0 minutes at low speed. A dose of .28 grams of surfactant, diluted in 50 ml of warm water, was added to the contents of the blender. The stock was slushed at low speed for 2.0 more minutes. The contents of the blender were then diluted with pH and temperature-adjusted tap water to the cell volume. A dwell time of 20 minutes was used, during which final temperature and pH adjustments were made.

Toward the end of the dwell period, the stock was transferred to the flotation cell. The compressed air jets were activated, along with the paddlewheel. Minimal dam adjustments were made, and the cell impeller was turned on. Air flow adjustments were immediately made. Flotation was continued for a period of 12 minutes.

At the end of the flotation run, all motors were turned off. The cell was emptied into pails. All material (i.e., foam, ink particles, fiber) retained by the cell also was washed into the pails.

Two handsheets were made of the flotated stock on the Noble

and Wood apparatus. The handsheets were dried and conditioned.

Nine brightness tests were made on each side of each sheet (wire and felt side). The total weight of each run was used for yield calculations. A panel of four people rated the handsheets for general appearance and cleanliness.

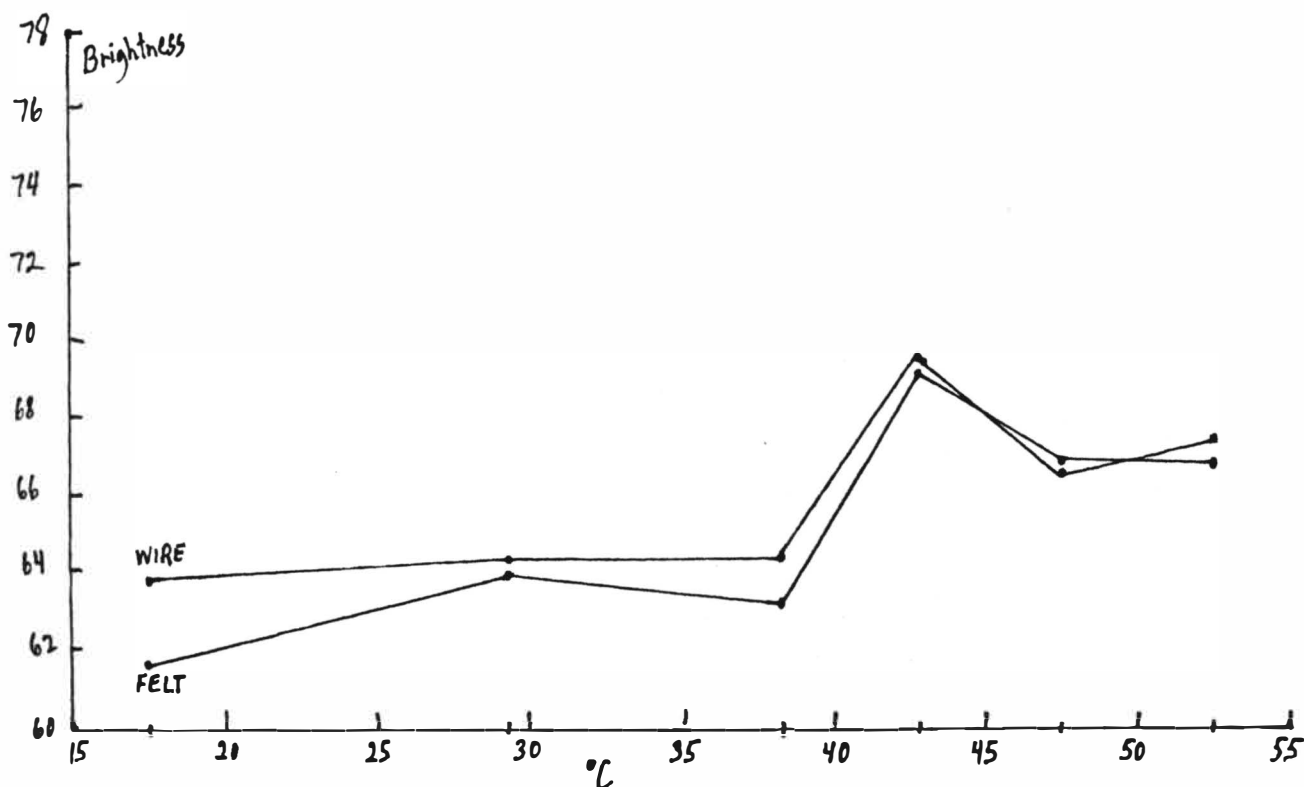
Discussion of Results

Experimental data is summarized in appendix IV.

Effect of Cell Temperature

Figure 3 is the graphical representation of brightness values vs cell temperature data. The relationship between cell temperature and resulting brightness for the UV-cured ink was not different from that of normal emulsifiable ink. Generally, at high temperatures, resulting higher brightness values were attained.

Figure 3: Brightness vs Cell Temperature



The large, sudden brightness increase near the 45°C temperature was seen. In fact, characteristics of the pulp stock were seen to change dramatically whenever the stock was raised in temperature above the 40°C mark. The stock was observed to 'break' (the ink particles resettled back into the

stock). It should be noted that the flotation process was most effective with stock in this condition.

Visual ranking data and yield calculations were not different from what would be expected by the brightness results.

Figure 4: Visual Ranking vs Cell Temperature

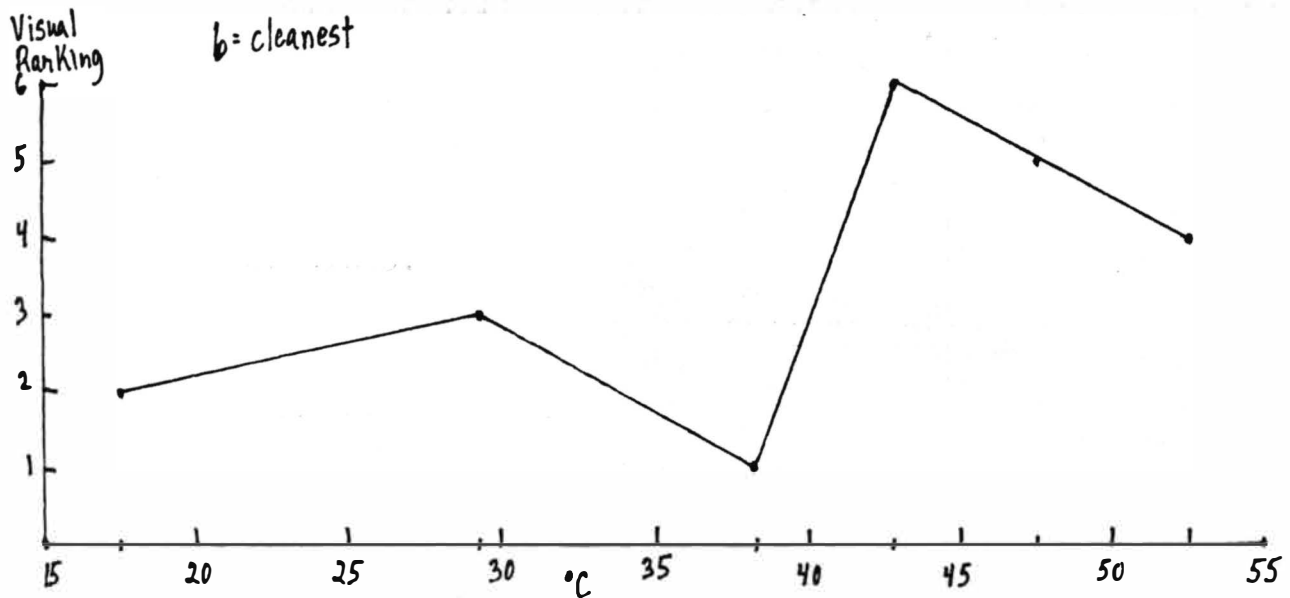
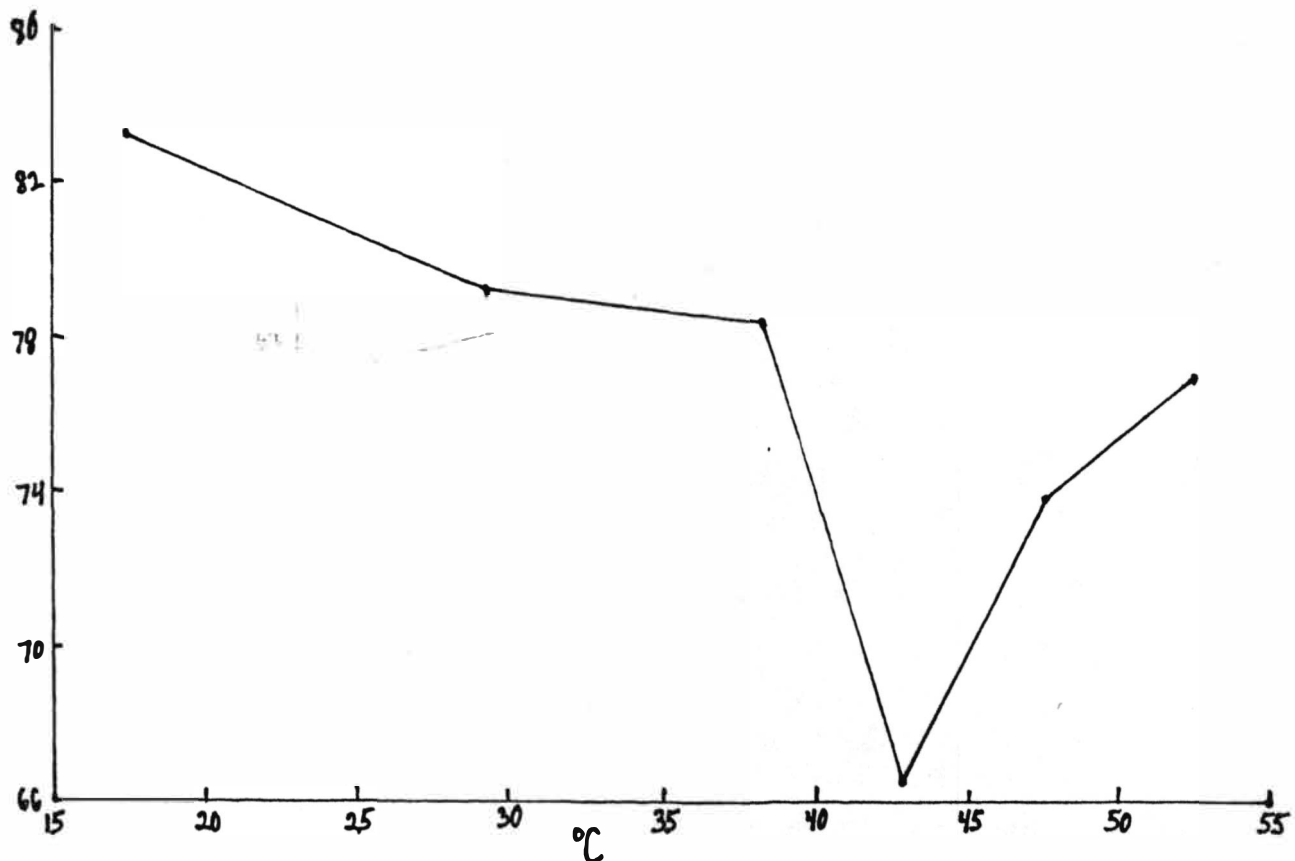


Figure 5: Yield vs Cell Temperature



It was desired to derive a method of describing the general character of the flotation operation in each run. These were assigned as one of two conditions:

Cell Limited In this situation, the ink particles floated to the surface but were not removed efficiently through the foam spout. At the end of the run, a significant amount of ink particles were still apparent on the stock surface.

Stock Limited In this condition, almost all ink which floated was effectively removed from the cell. At the end of the flotation period, very little ink remained on the stock surface.

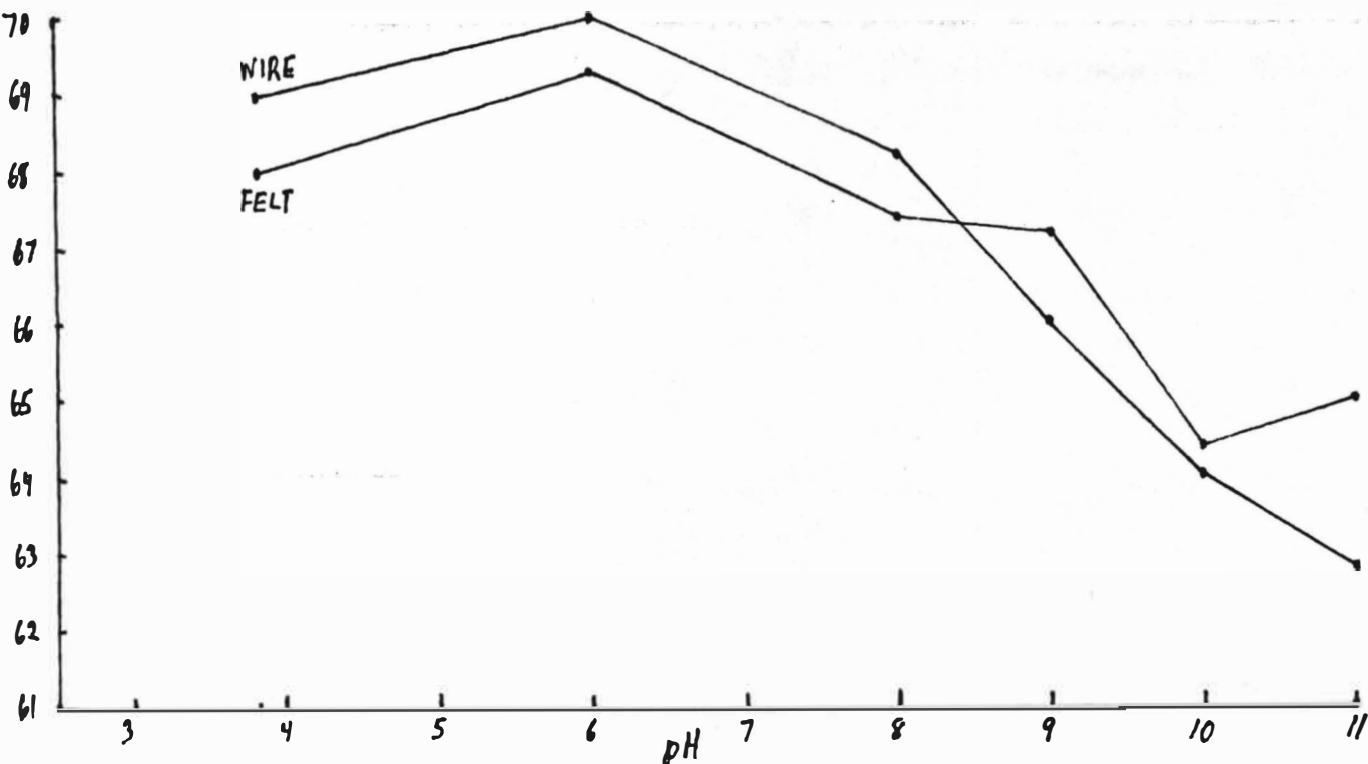
These two conditions were related to foam stability and the ability of the ink to float to the surface. Cell limited runs were seen as significant deviations in brightness between wire and felt sides of the Noble and Wood handsheets. As the handsheet formed, the ink particles floated to the surface of the stock chamber.

Effect of Cell pH

In this portion of the study, a completely different relationship between brightness and cell pH was found for the UV-cured ink as compared to normal emulsifiable ink. It was widely reported in the literature that pH in the range of 8-10 was desirable for maximum brightness increase for normal inks. However, it was found that for the UV-cured ink, low pH was desirable, with a maximum brightness near pH 6.0.

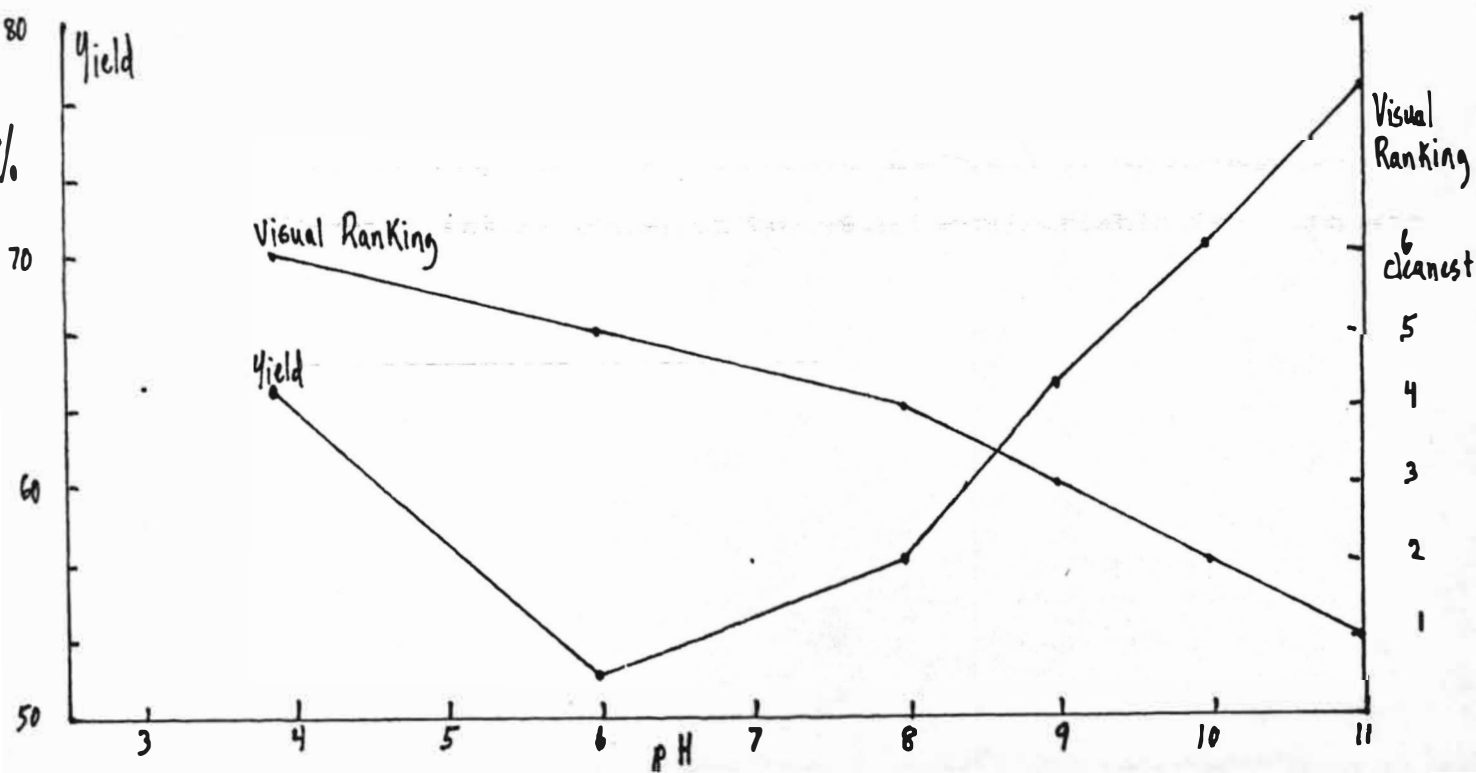
Figure 6 shows the relationship between brightness and pH.²⁵

Figure 6: Brightness vs Cell pH



Again, visual ranking and yields were compatible with the brightness data.

Figure 7: Visual Ranking and Yield vs Cell pH



Effect of Air Flow

The air flow was approximately twice as high in the temperature constant runs as in the pH constant runs. The effect of increase air flow can be seen below at the duplicated point of pH=8,0 and temp.=40 C.

Table 1: Brightness at Two Different Air Flows

<u>Air Flow</u>	<u>Brightness</u>	<u>Yield</u>
low	64.5 / 63.3	78.3
high	68.2 / 67.4	56.7
	(wire / felt)	

Although this represents just two data points, it was only desired to demonstrate that brightness was dependant on the air flow to the cell.

Summation of Conclusions

Optimum cell temperature in the flotation cell was found to be 40-45 C. The optimum temperature for UV-cured ink was similar to that for normal ink.

Optimum cell pH was found to be different for the UV-cured ink than for normal ink. Low pH (optimum of 6.0) gave the highest brightness values for UV-cured ink.

Suggestions for Further Work

As it has been shown that UV-cured ink (large particle size) reacts somewhat differently than normal emulsified ink (small particle size), it would be valuable to quantitatively relate particle size to flotation effectiveness.

LITERATURE CITED

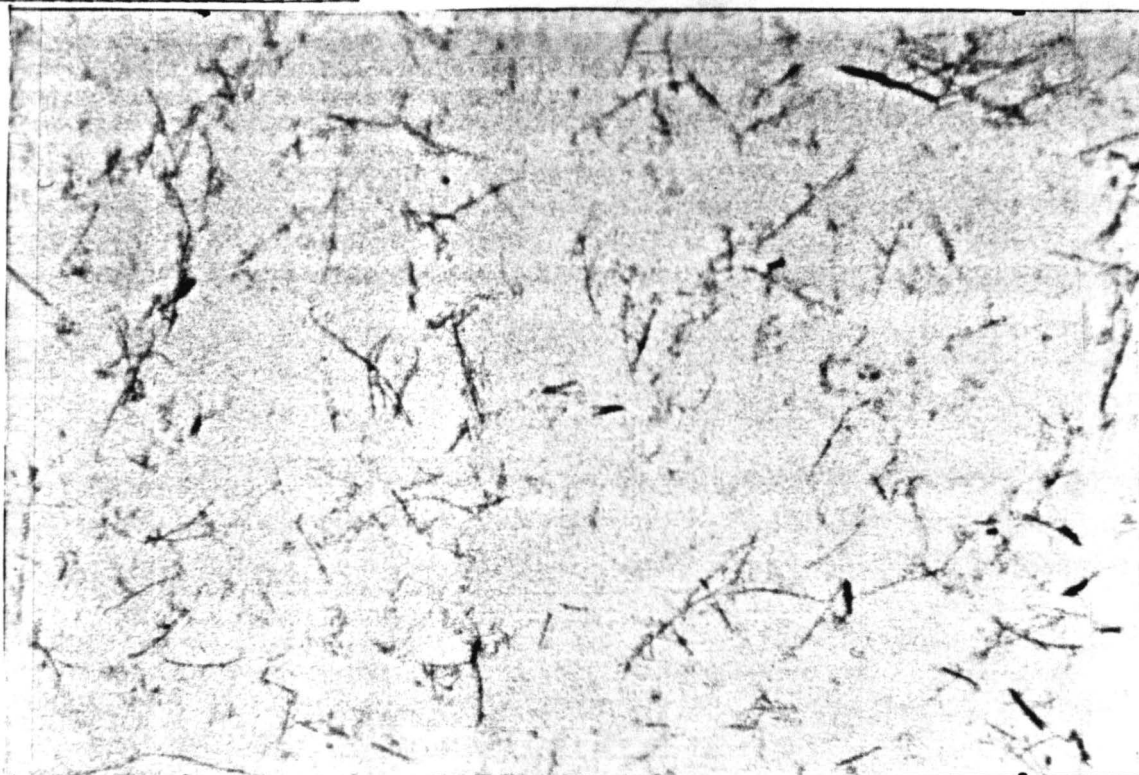
- (1) Shahidi, Dr. I.K., Powada, T.M., American Ink Maker, 53 (1):20 (1975).
- (2) Nass, G., American Ink Maker, 53 (6):25-29 (1975).
- (3) Vanderhoff, Dr. J.W., American Ink Maker, 51 (4):38 (1973).
- (4) "Electron Beam Technology," Encyclopedia of Chemical Technology, Vol. 13, John Wiley & Sons, NY (1981).
- (5) Bassemir, R.W., "UV Ink Chemistry: Paper and Paperboard," American Ink Maker, 52 (12) (1974).
- (6) Raimondo, Frank E., Tappi, 50 (9):69-74A (1967).
- (7) Matzke, Dr.W., Paper Maker, 163 (5):38-44 (1972).
- (8) Cody, Harold M., Pulp and Paper, 52 (11):123-130 (1978).
- (9) Mack, H., Tappi, 46 (3):141A (1963).
- (10) Wultsch, F., Tappi, 46 (3):147A (1963).
- (11) Gaudin, A.M., Floatation, 2nd ed., McGraw-Hill, 1957.
- (12) Rosen, Milton J., "Surfactants and Interfacial Phenomenon," Wiley-Interscience Publications, John Wiley & Sons, New York, 1978.
- (13) "Flotation," Encyclopedia of Chemical Technology, Vol.9, John Wiley & Sons, New York, 1966.
- (14) Canadian Pulp and Paper Industry, 29 (10):29 (1976).
- (15) Jelks, J.W., Paper Trade Journal, 134 (17):22 (1952).
- (16) Chemical Week, 120 (14):30 (1977).
- (17) Pulp and Paper International, 20 (6):56-63 (1978).
- (18) Mattingly, Dr., Pulp and Paper International, 20 (6):64 (1978).
- (19) Somasundaram, P., "Separation and Purification Methods," Marcel Dekker Inc., Vol. 1, 1972.

- (20) Adamson, A.W., Physical Chemistry of Surfaces, Interscience Publishers, New York, 1960.
- (21) Griffin, W.C., Journal of the Society of Cosmetic Chemistry, 1:311 (1949).
- (22) Bassemir, Robert W., Tappi, 62 (7):25-26 (1979).
- (23) Hellberg, E.Valentine, Pulp and Paper International, 18 (10):55-59 (1979).
- (24) Falcone, James S., and Spencer, Rober W., Pulp and Paper, 49 (14):114-117 (1975).
- (25) Turai, Leslie L., and Williams, Lawence D., Tappi, 60 (11):167-168 (1977).
- (26) Jelks, J.W., Tappi, 37 (10):176A (1954).
- (27) Ortner, H., Tappi, 48 (2):37A (1965).
- (28) Miller, Jeffery F., "The Effect of HLB of Surfactants in Flotation Deinking of Electron Beam-Cured Ink," Thesis, Western Michigan University, Kalamazoo, MI (1983).
- (29) Lemlich, R., "Adsubble Methods," Recent Developments in Separation Science, CRC, 1972.
- (30) Williamson, R., Paper, 192 (3):121-129 (1979).
- (31) Pfalzer, L., Tappi, 63 (9):113-116 (1980).
- (32) Chemistry and Physics of Interfaces, II, American Chemical Society Publications, Washington D.C., 1971.
- (33) Klassen, V.I., and Mokrousov, V.A., An Introduction to the Theory of Flotation, Butterworths, London, 1963.
- (34) Lemlich, R., "Principles of Foam Fractionation," Progress in Separation and Purification, Interscience Publishers, 1968.
- (35) Fuerstenau, D.W., Pure and Applied Chemistry, 24 (135) (1970).
- (36) Sutherland, K.L., Journal of Physical & Colloid Chemistry, 52:394 (1966).
- (37) Chemical Week, 120 (14):30 (1977).

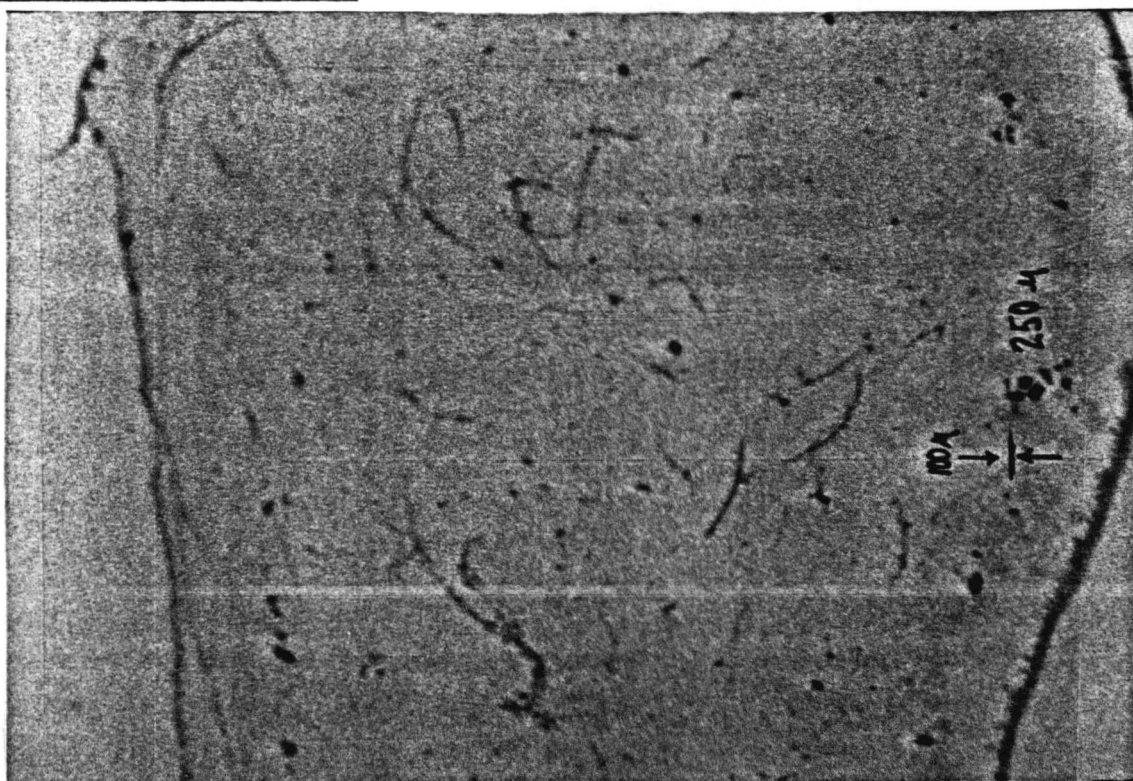
APPENDIX I

Photographs of Inked Pulp (Same Scale)

Normal Emulsified Ink



Ultraviolet-Cured Ink



APPENDIX II

Experimental Design, Run Conditions

Run No.	<u>Temperature (°C)</u>		<u>pH</u>		<u>Limit</u>
	<u>Target</u>	<u>Actual</u>	<u>Target</u>	<u>Actual</u>	<u>Condition</u> *
1	20.0	17.5	8.0	8.0	Cell
2	30.0	29.2	8.0	8.0	Cell
3	40.0	38.2	8.0	8.0	Cell
4	45.0	42.8	8.0	8.0	Stock
5	50.0	47.5	8.0	8.0	Stock
6	60.0	52.5	8.0	8.0	Stock
7	40.0	38.0	4.0	3.8	Cell
8	40.0	37.0	6.0	6.0	Cell
9	40.0	37.0	8.0	8.0	Stock
10	40.0	37.5	9.0	9.0	Stock
11	40.0	37.0	10.0	10.0	Stock
12	40.0	38.0	12.0	11.0 **	Stock

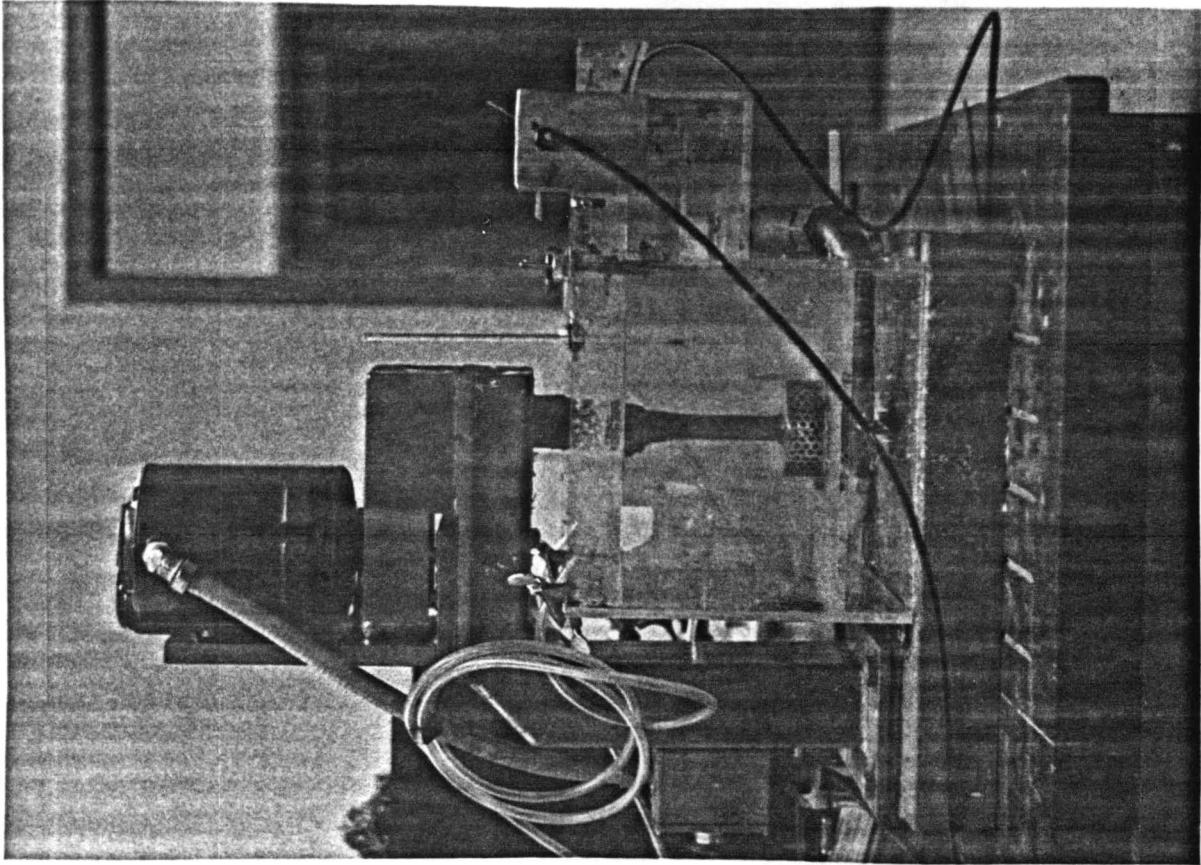
* Refers to flotation characteristics of the stock.

Please see "Discussion of Results".

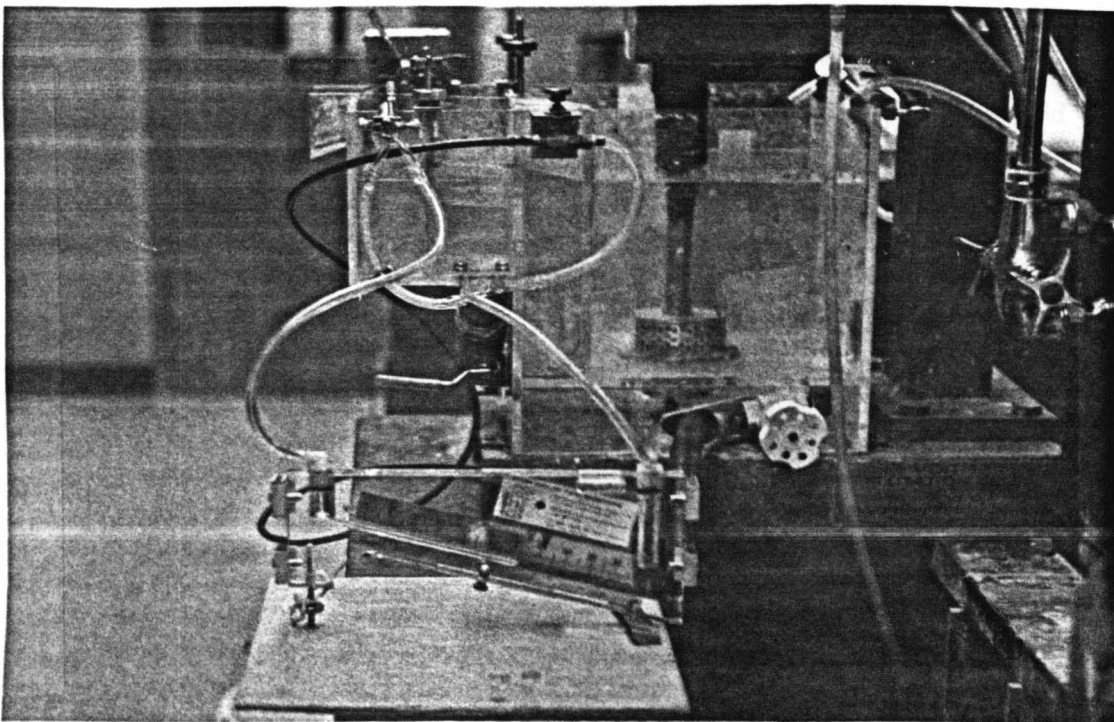
** pH of stock would go no higher.

APPENDIX III

Voith Laboratory Flotation Cell



Air Flow Control Apparatus



APPENDIX IV

Experimental Results

Run	Brightness	Cell Yield	Visual
<u>No.</u>	<u>(wire/felt)</u>	<u>(%)</u>	* <u>Ranking</u>
1	63.8/61.6	83.3	2
2	64.4/64.0	79.3	3
3	64.5/63.3	78.3	1
4	69.5/69.2	65.3	6
5	66.7/66.9	73.6	5
6	67.6/66.9	76.8	4
7	69.0/68.0	64.2	6
8	70.7/69.3	51.7	5
9	68.2/67.4	56.7	4
10	66.0/67.2	64.2	3
11	64.0/64.4	70.1	2
12	62.8/65.0	76.8	1

* 1=cleanest, 6=dirtyest