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(Study of Coater)
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TRAILING BLADE COATING EXPERIMENTS

Effect of Trailing Blade Pressure on
Weight of Coating and Surface Properties

The trailing blade coating method has received increased attention by the paper industry (1 through 8). This is largely due to its ability to apply a level coating especially suitable for printing requirements. It appears especially attractive to paperboard producers as it is reported to eliminate the need for calendering which causes a reduction in caliper and a loss in desired stiffness.

This report describes tests which were made to learn more about the operation of the trailing blade coater and to provide an opportunity for demonstrating the operation of the Institute's experimental coater to one of the participants in the Industry Seminar who had been assigned to report on a comparison of coating methods.

PROCEDURE

The base stock used in the coating experiments was a publication grade paper with a starch coating on one side. The clay coating was applied to the uncoated side of the paper.

The coating color was prepared according to Formulation 1819-42.

Coating Color 1819-42

Water	43 lb.	
Calgon T	2 lb.	
TiO_2 (Titanox RA-50)	25 lb.	
$CaCO_3$	25 lb.	
Clay (Premax)	50 lb.	
Alpha protein solution		
Alpha protein	2 lb.	
Water	8 lb.	
Concentrated NH_4OH	57 ml.	
Dow 512-L Latex	31.2 lb.	
Dowicide G	0.74 lb.	
Water (plus 50 ml. conc. NH_4OH)	4.75 lb.	(added at the coater supply tank)

The water, dispersing agent, and pigment were milled for 15 minutes in Model O Kady Mill. The alpha protein solution cooked at 90 to 95°C. for one hour and then cooled to 45 to 50°C. before adding.

Note: Final solids - 61%
Viscosity (Hercules High Shear Viscometer), cps. - 52
Viscosity (Brookfield Spindle #3 at 60 r.p.m.), cps. - 1,004

The coating color was prepared by milling the pigment in water with the dispersing agent for 15 minutes in a Model O Kady Mill. The alpha protein solution was prepared separately and then added to the coating color by mixing for two minutes in the Kady Mill. The Dow 512-L latex was added to the formulation in the Kady Mill. Dowicide G was added to protect the protein against bacterial action.

The hot coating color tended to form a skin as soon as the agitation was stopped. An additional amount of water and concentrated ammonium hydroxide were added to obtain a smooth mix.

The viscosity of the coating color was determined at varied rates of shear with the Brookfield Model LV and the Hercules High Shear viscometers.

The solids content of the coating color was determined by drying three one-gram samples at 110°C. for 16 hours in an air-circulating oven.

The trailing blade fountain was mounted on ball bearings (see Fig. 1) to permit measurement of the pressure of the blade against the paper. Two dams of solder, not shown in the sketch, were added at a place 1-1/2 inches from the slot openings to minimize loss of oil and to prevent contamination of the bearings.

A dial indicator with one-inch travel was mounted at the side of the fountain to ascertain the amount of movement as the blade was forced against the paper at different pressures.

The threadup for trailing blade coating is shown in Fig. 2 which shows the assembly of coaters with which the experimental coater is now equipped. The coating color was not recirculated in these tests due to a last-minute failure of one of the pumps.

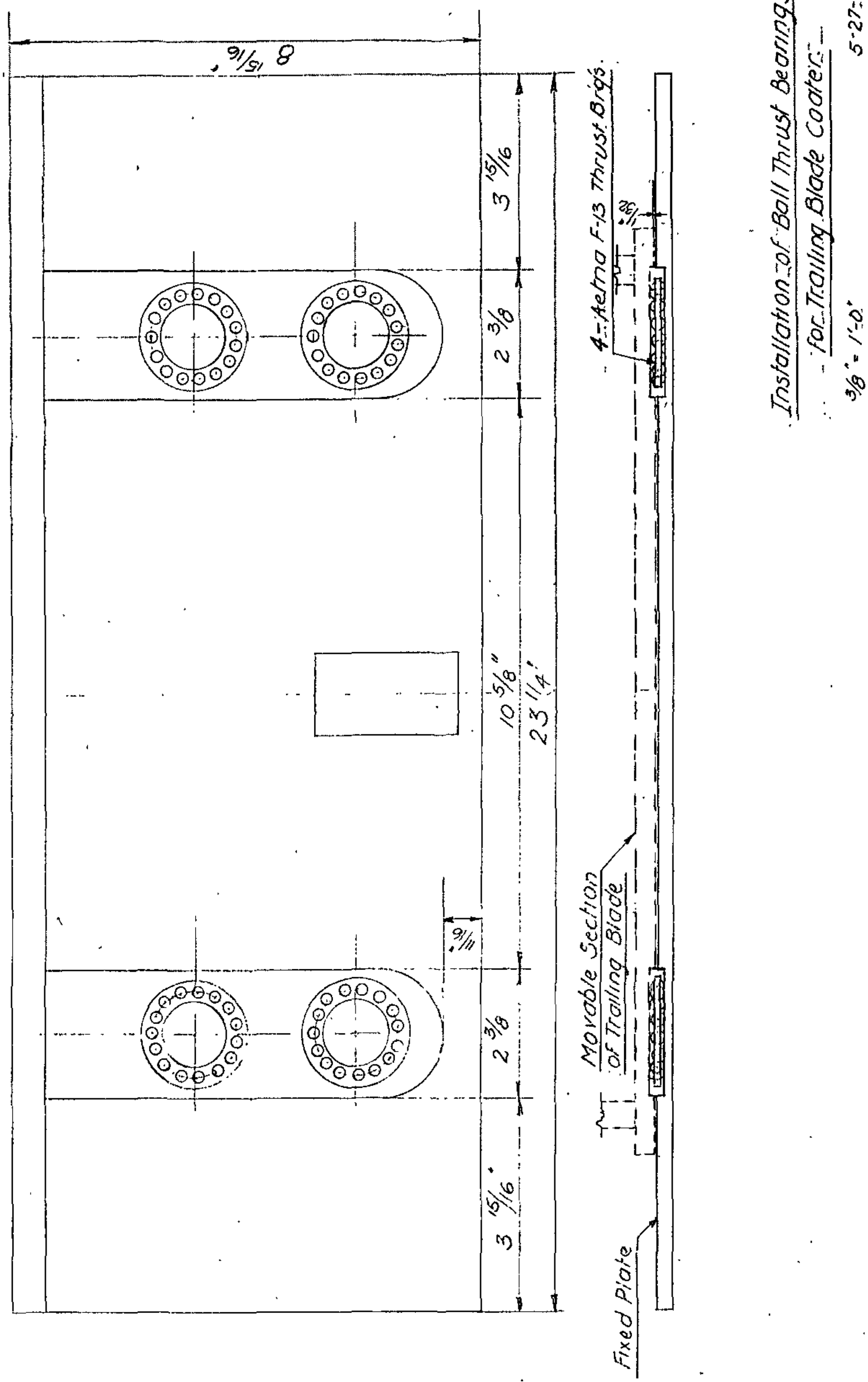
The heaters in the drying section were set at maximum temperature and the retractable heaters were as close to the paper as possible without contact.

The coating experiments included a variation of the pressure applied to the trailing blade and a variation in speed of coating. Maximum speed was not reached in these trials which were halted when the supply of paper was exhausted.

The machine conditions used are summarized in Table I.

Figure 1

Ball Bearing Support for Trailing Blade and Fountain



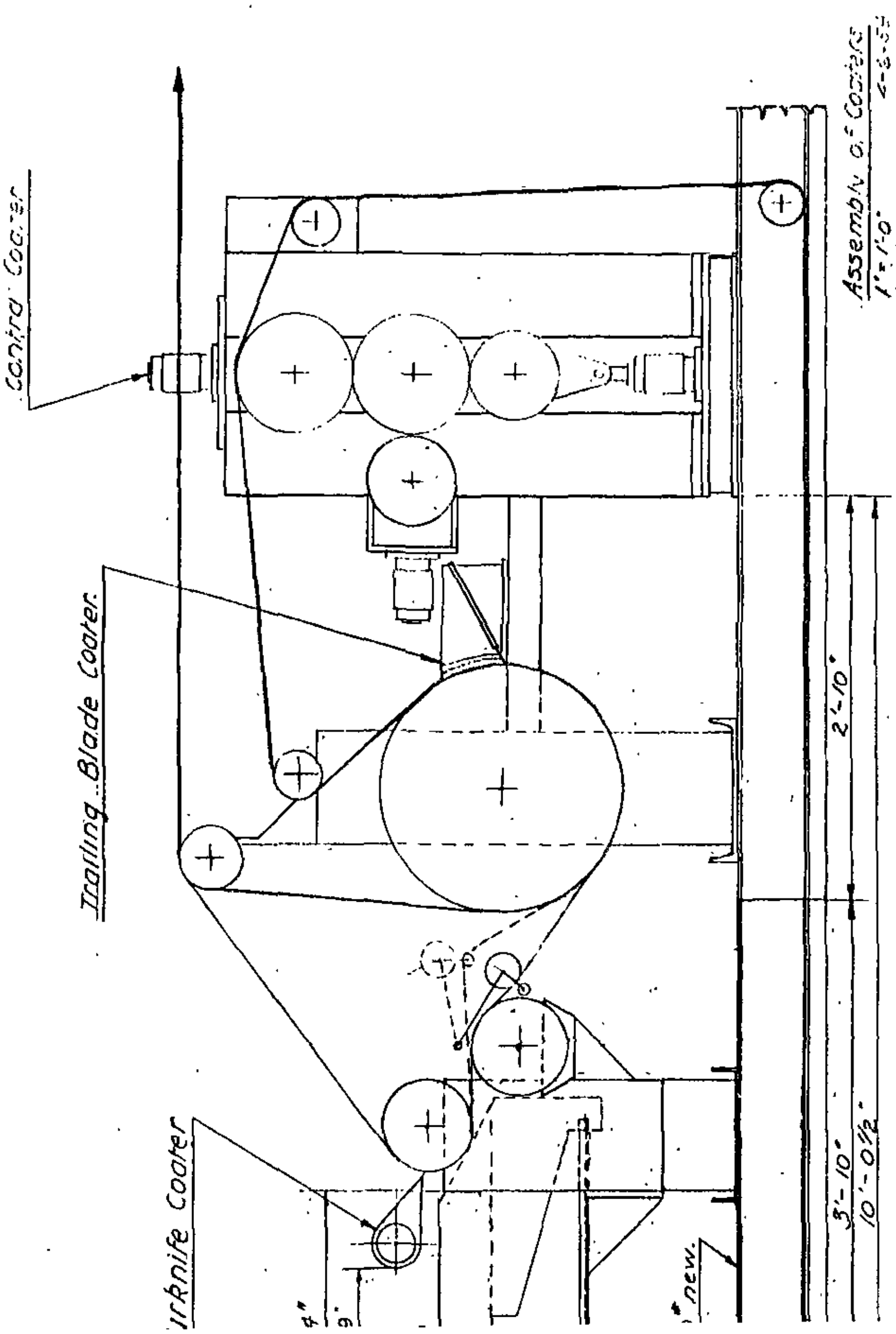


Figure 2

used in Trailing Blade Coating Method

TABLE I

TRAILING BLADE COATING CONDITIONS

Run	Speed, ft./min.	Air Pressure, p.s.i.	Thrust,[1] lb./in.	Blade Movement,[2] Inch	Coating Weight[3] lb./ream (24X36--500)
1	600	50	70.8	.127	3.87
2	600	40	70.8	.127	3.75
3	200	40	70.8	.109	2.85
4	600	20	35.4	.107	2.97
5[4]	600	15	26.6	.094	2.86
6	700	40	70.8	.127	3.58
7	800	40	70.8	.127	4.13

Note: The heaters were set at maximum. Blade extension was13/16".

[1]The fountain support apparently came against a stop and the actual thrust on the blade could not be determined from the air pressure applied at the actuating cylinder.

[2]Determined with a one-inch travel dial indicator.

[3]Determined by weighing ten 3-1/8-inch diameter oven-dried die-cut disks of coated and uncoated paper.

[4]The dams at the edge of the fountain leaked.

Samples of coated and uncoated paper were conditioned and then calendered by giving 6-inch wide by 12-inch long strips four passes through a 2-roll calender at a nip load of 312 lb. per inch of nip.

Samples of calendered and uncalendered paper were tested for Chapman smoothness (9), Bausch and Lomb gloss (10), and Larocque print quality (11).

Photographs of the surfaces of the paper were taken at 20X while illuminated at 20° with the surface and across-the-machine direction.

The coating weights were determined from the difference in weight between coated and uncoated samples of paper which were oven dried.

RESULTS AND DISCUSSION

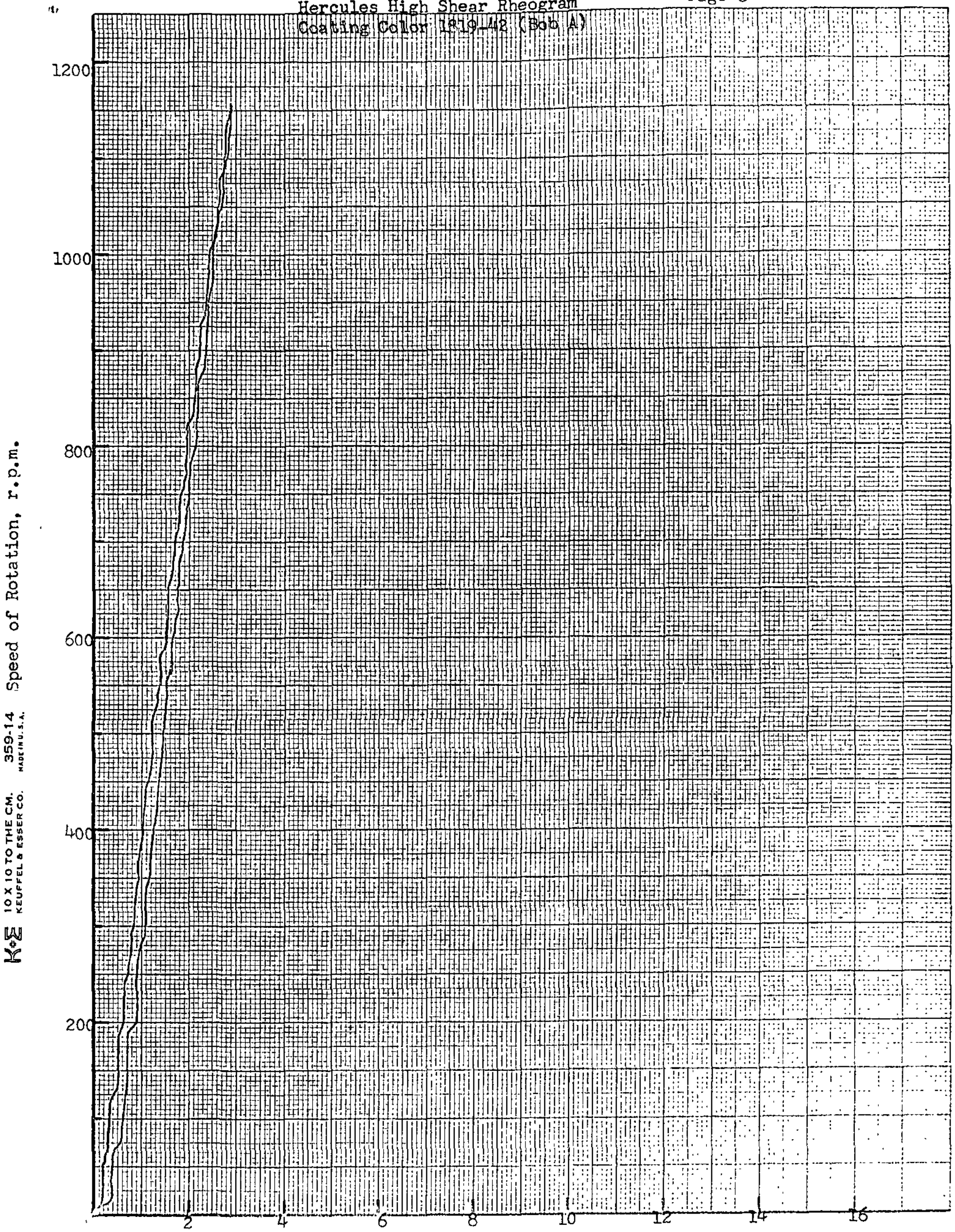
The coating color was applied at approximately 61% solids with no difficulty; higher solids could have been handled readily by the trailing blade. The viscosity of the coating color was 52 centipoises at 1150 r.p.m. as measured with the Hercules High Shear Viscometer and the Type A bob (see Figure 3). The Brookfield viscosity was 1,004 centipoises at 60 r.p.m. when tested with the No. 3 spindle (Table II).

A maximum speed of only 800 feet per minute was used due to the limited supply of the paper selected for these tests. Speeds up to 2,400 feet per minute are possible with the 15 h.p. Reliance d.c. drive.

The drive functioned satisfactorily provided the rate of acceleration was not too great, otherwise the torque-limiting clutch would throw out.

Figure 3

Hercules High Shear Rheogram
Coating Color 1819-42 (Bob A)



Torque x 10^{-5}, dyne cm.

TABLE II

BROOKFIELD VISCOSITY OF
1819-42 TRAILING BLADE COATING COLOR

RPM	Reading[1]	Factor	Viscosity, cps.
6	24.7	200	4940
12	30.0	100	3000
30	38.5	40	1540
60	50.2	20	1004
30	38.3	40	1532
12	30.2	100	3020
6	25.5	200	5100

[1]Spindle No. 3

Solids content: 60.96%

The clutch is rated at 1/2 h.p. at 100 r.p.m. When possible, it should be replaced with one of 5 h.p. capacity. This would provide adequate protection for the chain drive and permit faster acceleration.

The trailing blade functioned smoothly with a few exceptions. The coating weight varied from 2.85 to 4.13 lb. per ream (24X36--500). The edge dams tended to leak when the pressure on the knife was reduced. The dams had to be repositioned to minimize leaking. We have since obtained samples of plastic and rubber foam with which we will try to back the felt dams to permit variation of pressure and minimize leaking.

The movement of the fountain was not entirely satisfactory. However, the coating weight could be varied by changing the thrust of the blade (see Figure 4). The coating weight could also be varied by changing the speed (see Figure 5). Future tests should probably be made by using mechanical stops with an excess air pressure to assure positive positioning of the fountain. Movement or bending of the blade may be measured with strain gages or a differential linear transformer.

The photographs of the surfaces (Figure 6) show no apparent pattern due to the coating process used. The fibrous structure of the sheet is evident in each case. Heavier coating weights would apparently be required to completely cover the fibers.

The cross section photographs (Figure 7) reveal that the average thicknesses of the coatings appear to vary from 12 to 15 microns. The cross section of a British commercial on-the-machine coating on esparto shows a comparable thickness. The coating thickness for Time magazine paper is also in the same range. Where the structure of the paper appears to be very rough

Figure 4

Effect of Varying Thrust
on Trailing Blade on Coating Weight

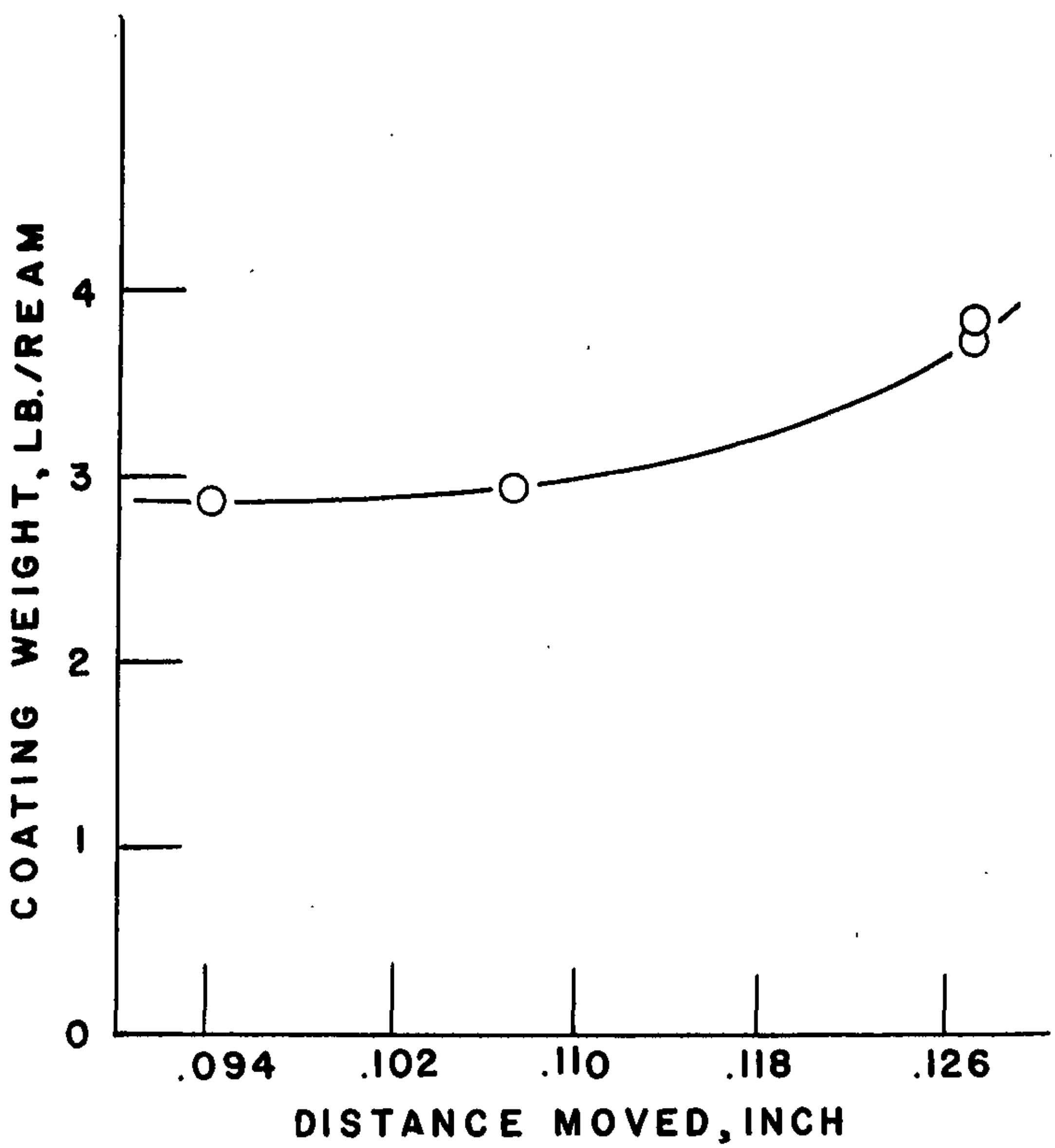


Figure 5

Coating Weight as a Function of Speed

(Trailing Blade Coating at 61% Solids)

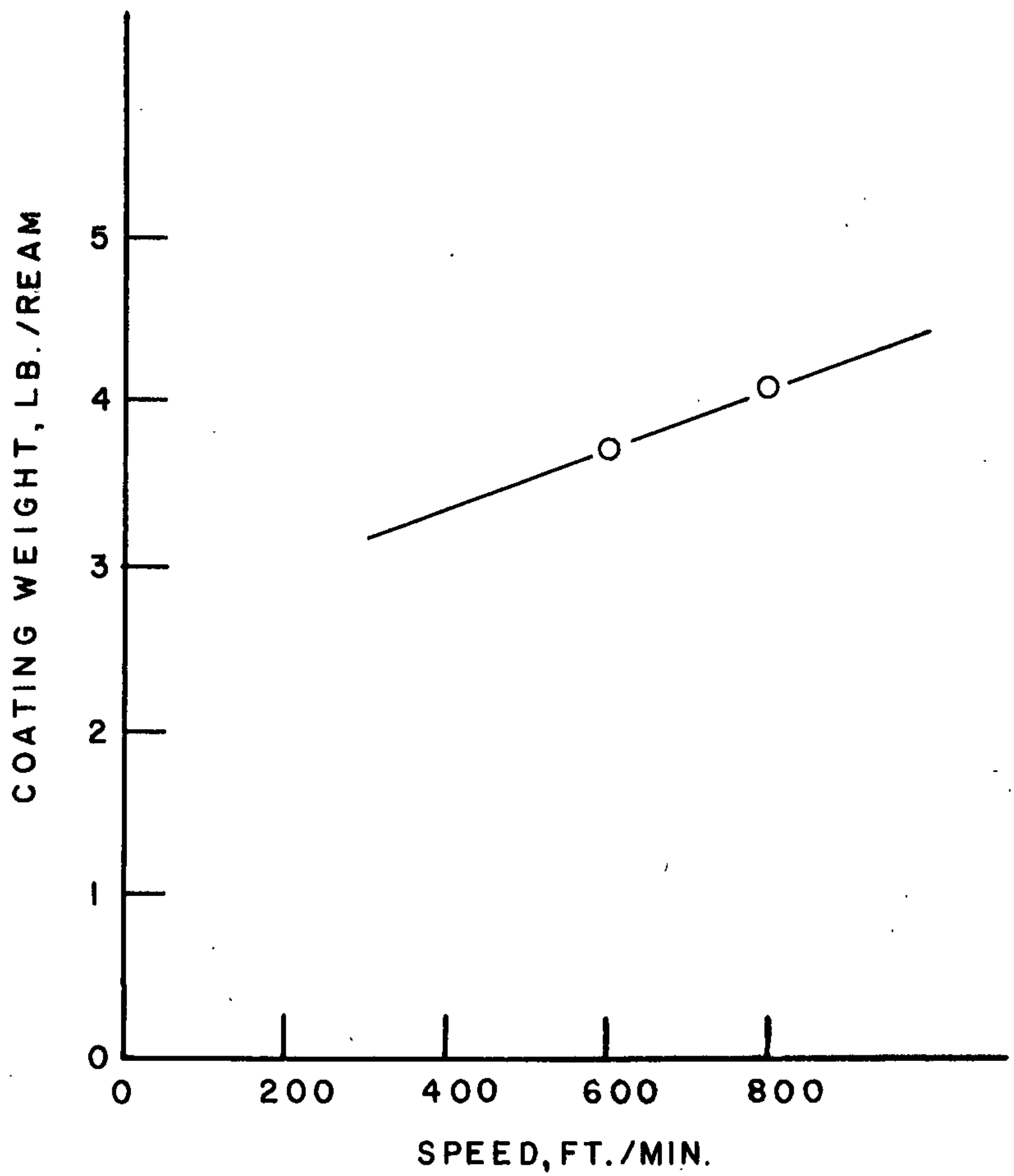


Figure 6

Uncoated Paper - Uncalendered
20X Oblique Illumination
(Angle of Incidence=85°)

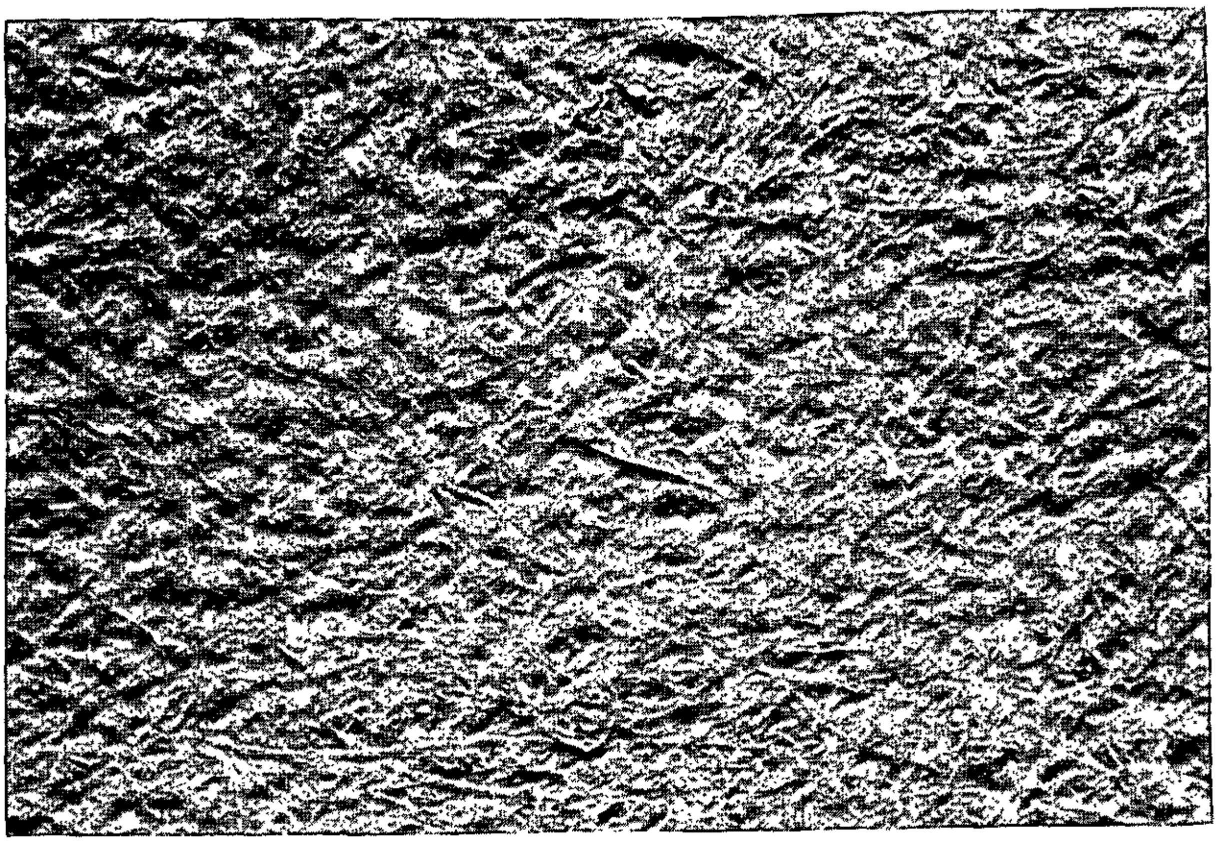


Figure 6 (Continued)

Uncoated Paper - Calendered
20X Oblique Illumination
(Angle of Incidence=85°)

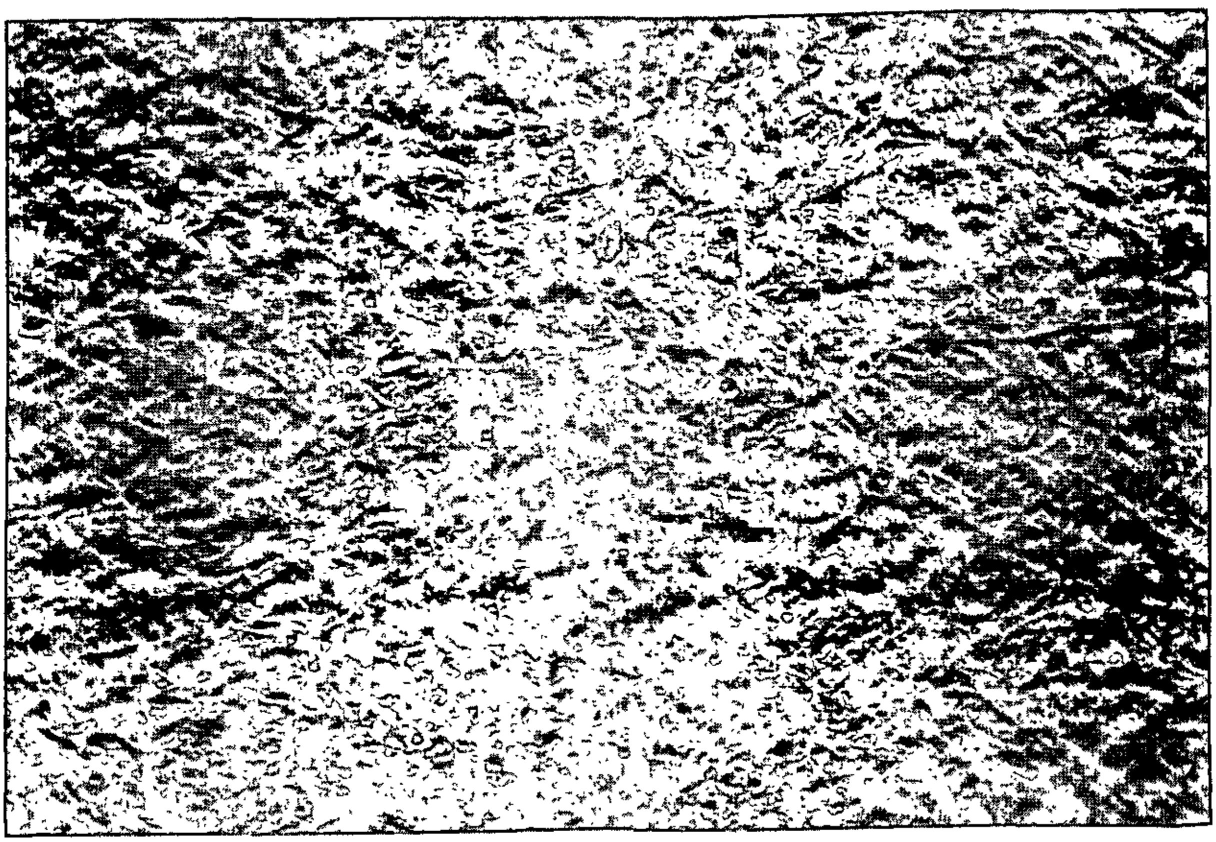


Figure 6 (Continued)

Run 1 Uncalendered (3.87 lb./ream, 600 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

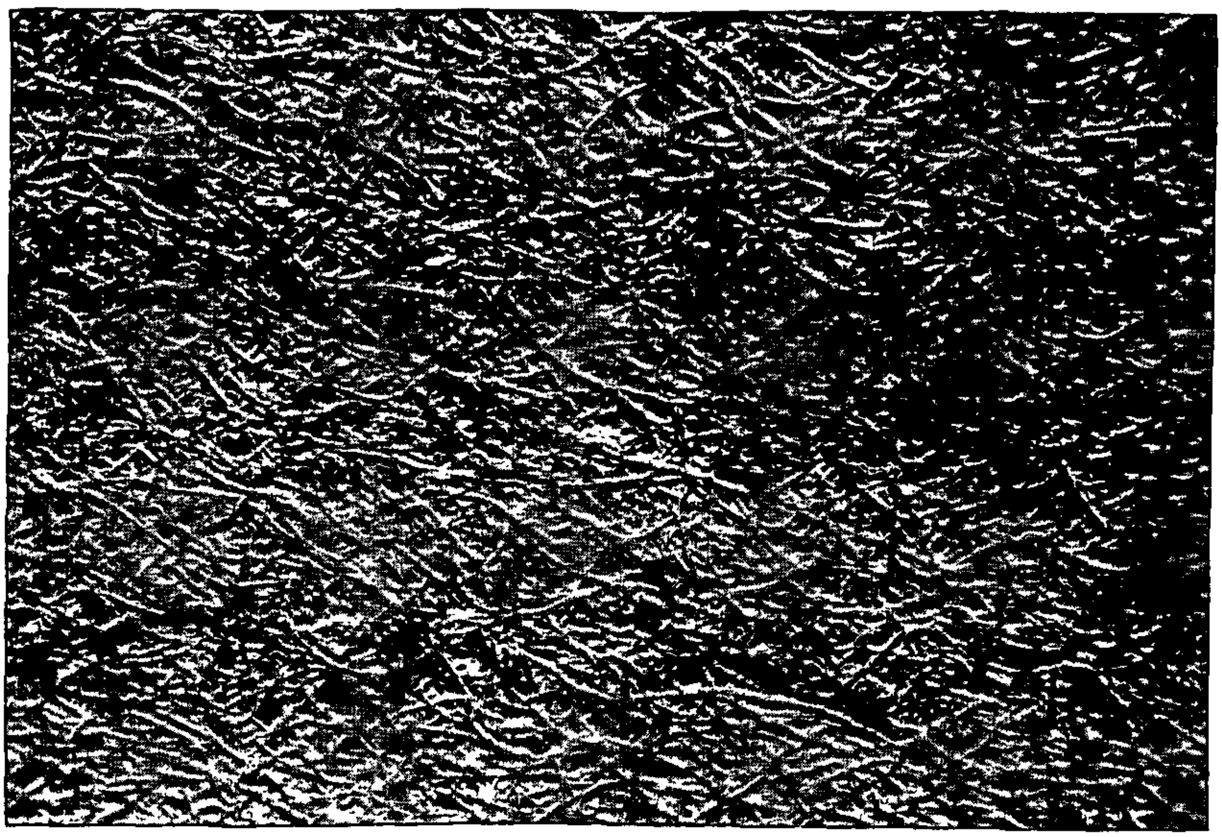


Figure 6 (Continued)

Run 1 Calendered (3.87 lb./ream, 600 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

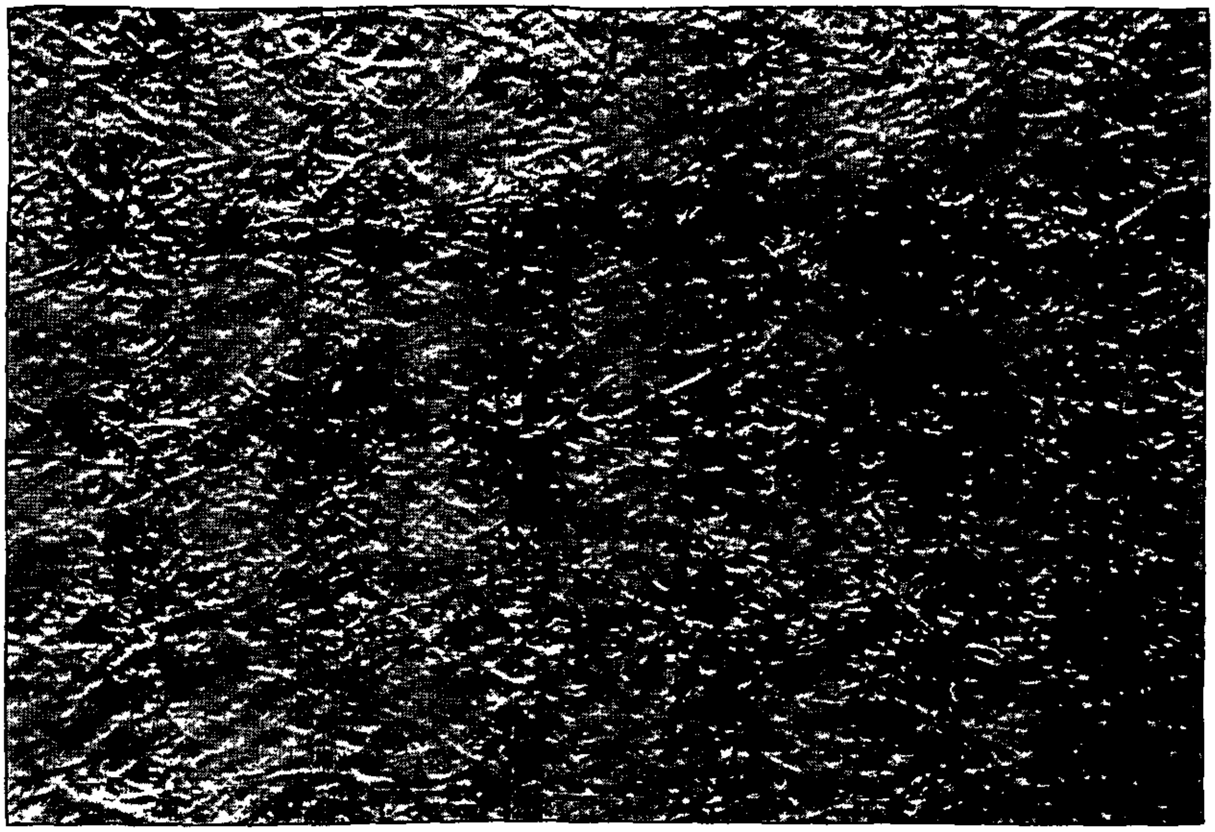


Figure 6 (Continued)

Run 2 Uncalendered (3.75 lb./ream, 600 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

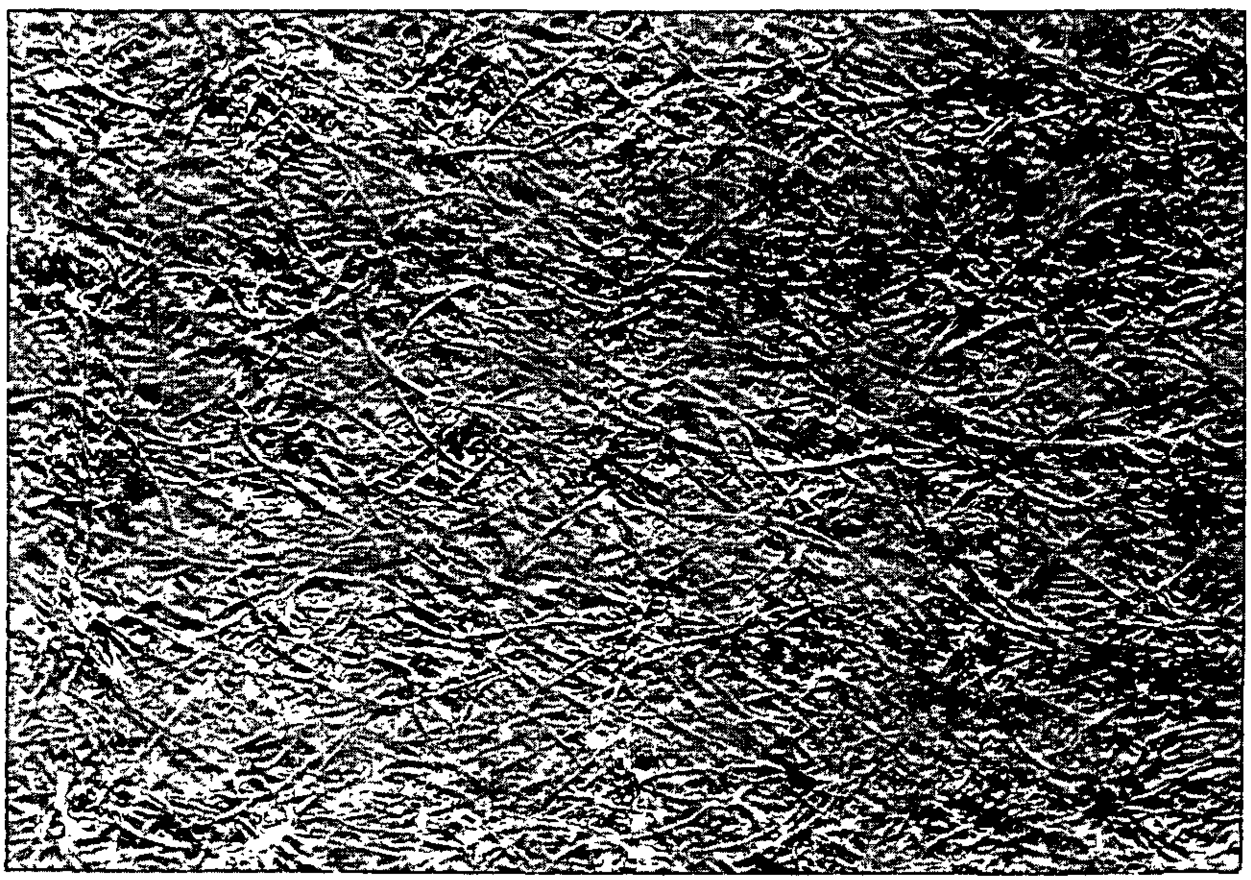


Figure 6 (Continued)

Run 2 Calendered (3.75 lb./ream, 600 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

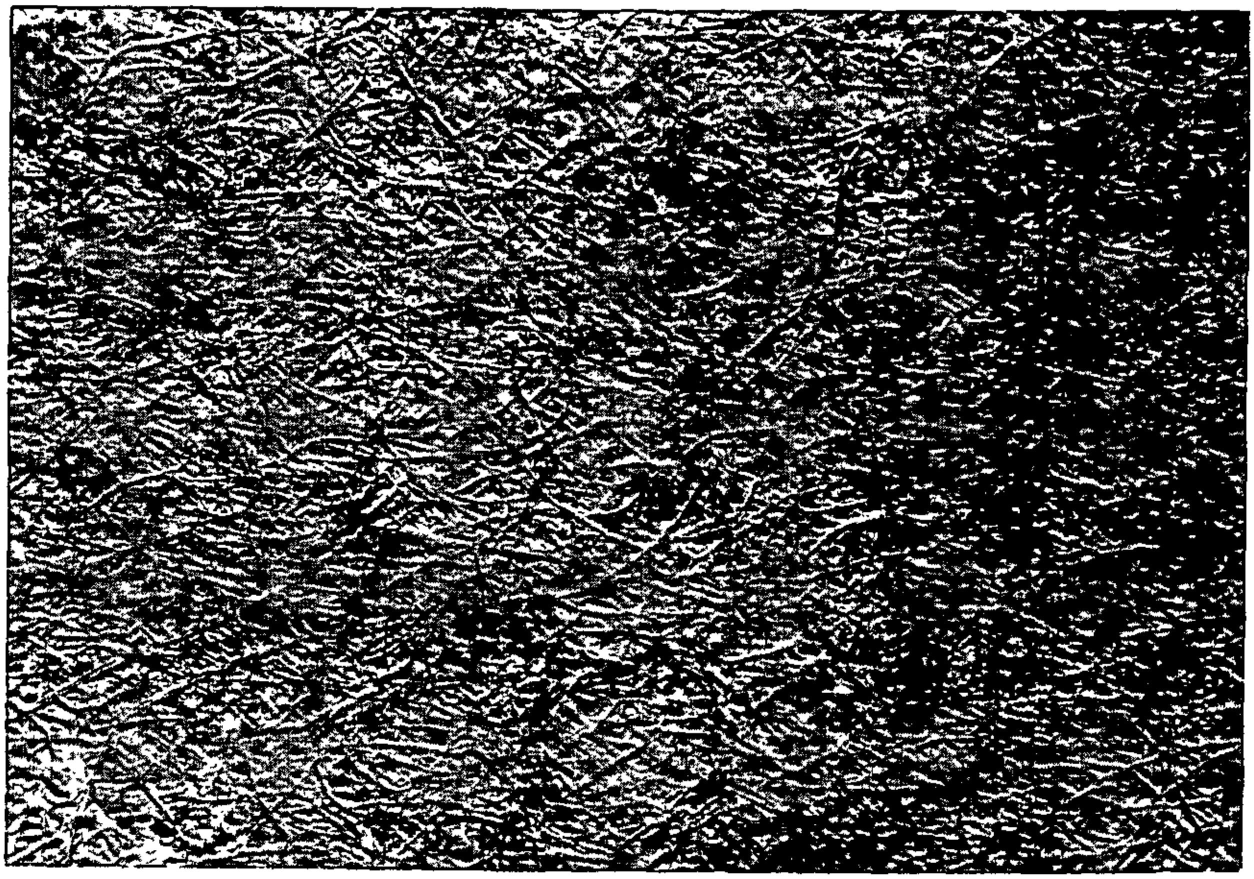


Figure 6 (Continued)

Run 3 Uncalendered (2.85 lb./ream, 200 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

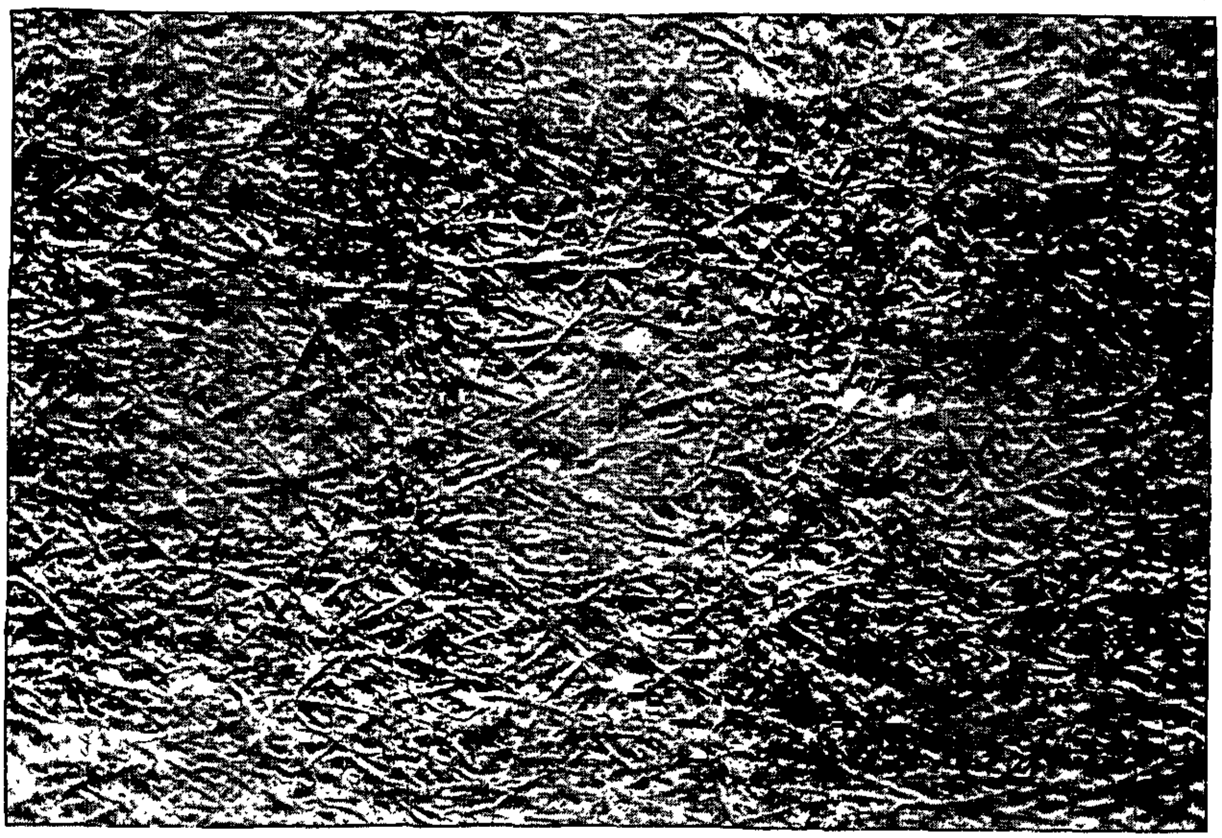


Figure 6 (Continued)

Run 3 Calendered (2.85 lb./ream, 200 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

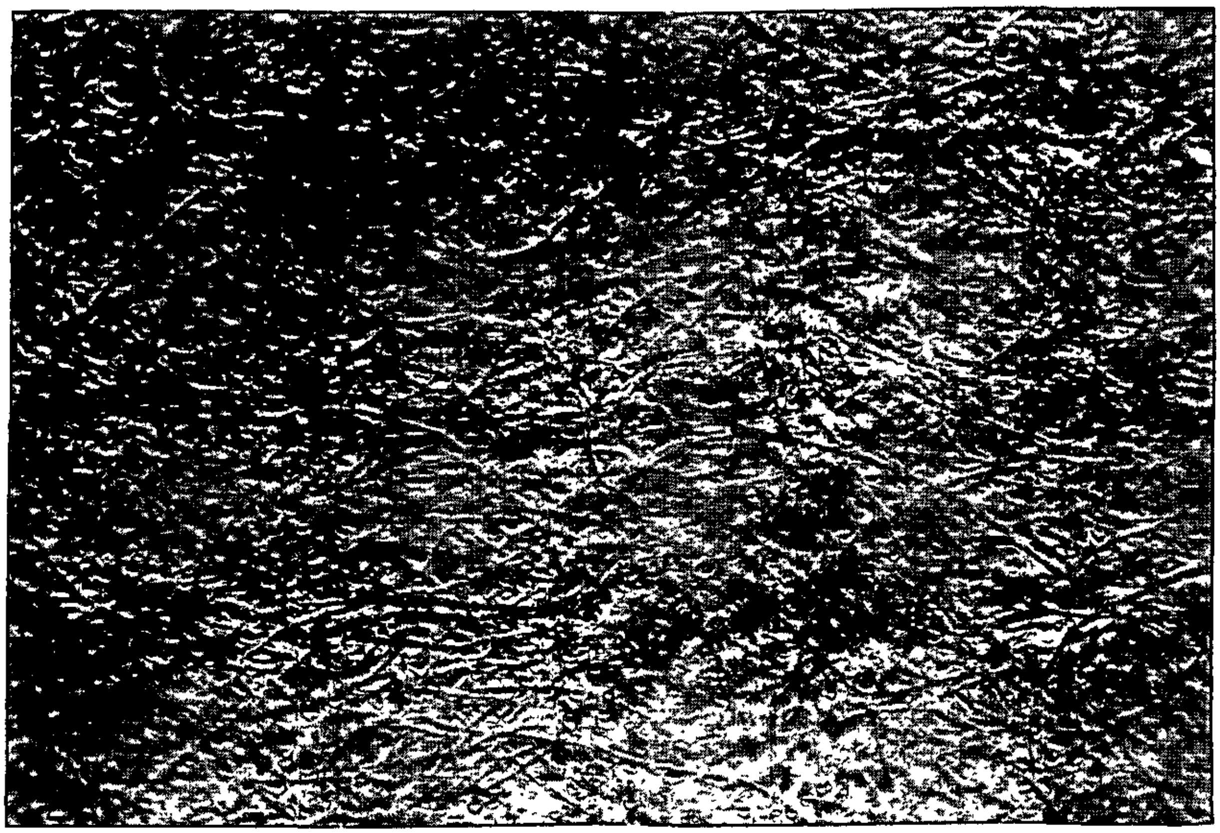


Figure 6 (Continued)

Run 4 Uncalendered (2.97 lb./ream, 600 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

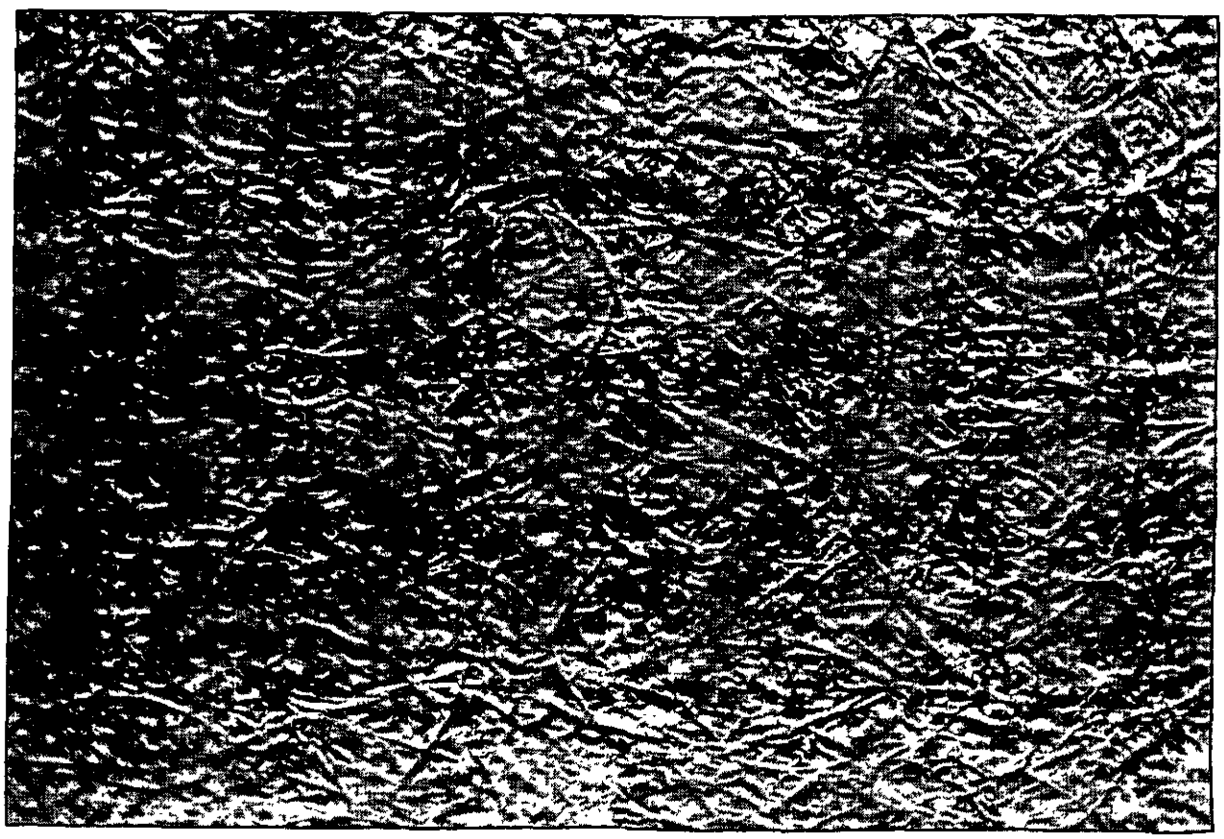


Figure 6 (Continued)
Run 4 Calendered (2.97 lb./ream, 600 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

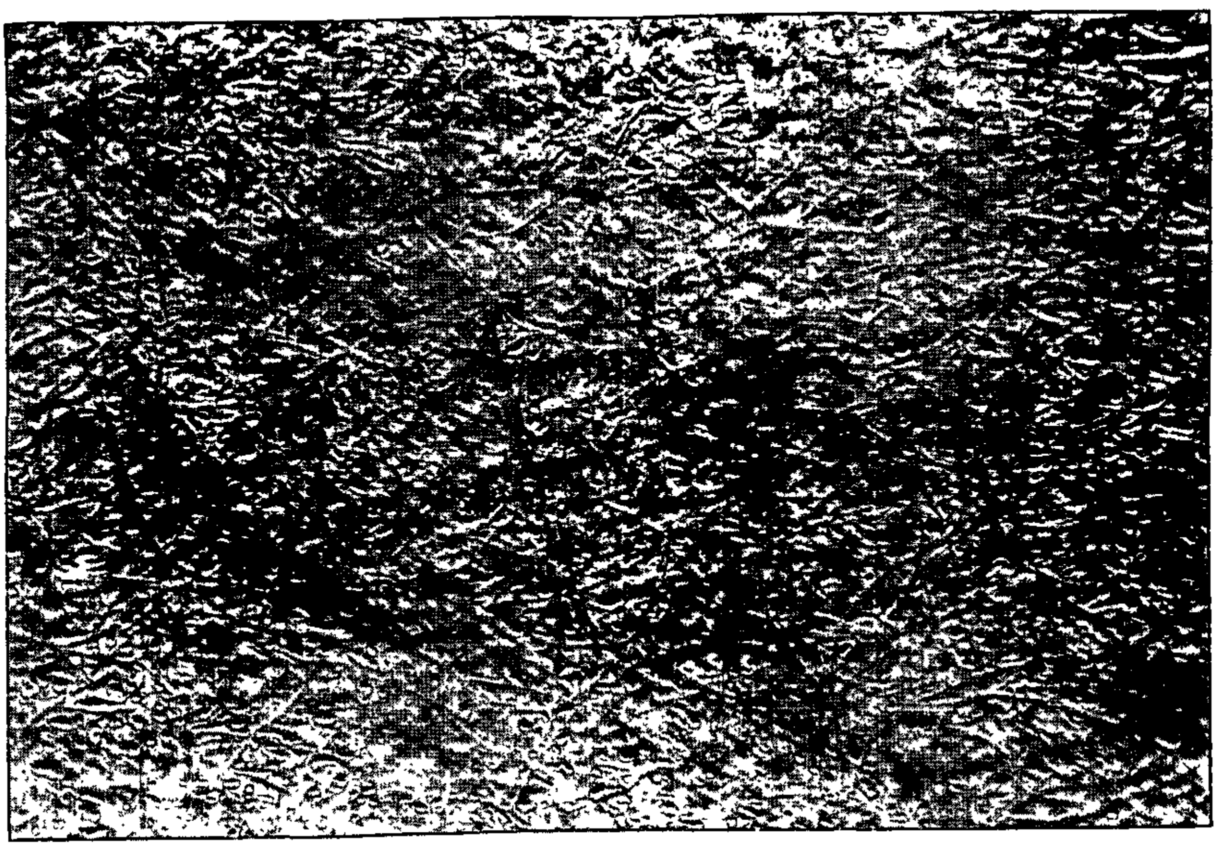


Figure 6 (Continued)

Run 5 Uncalendered (2.86 lb./ream, 600 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

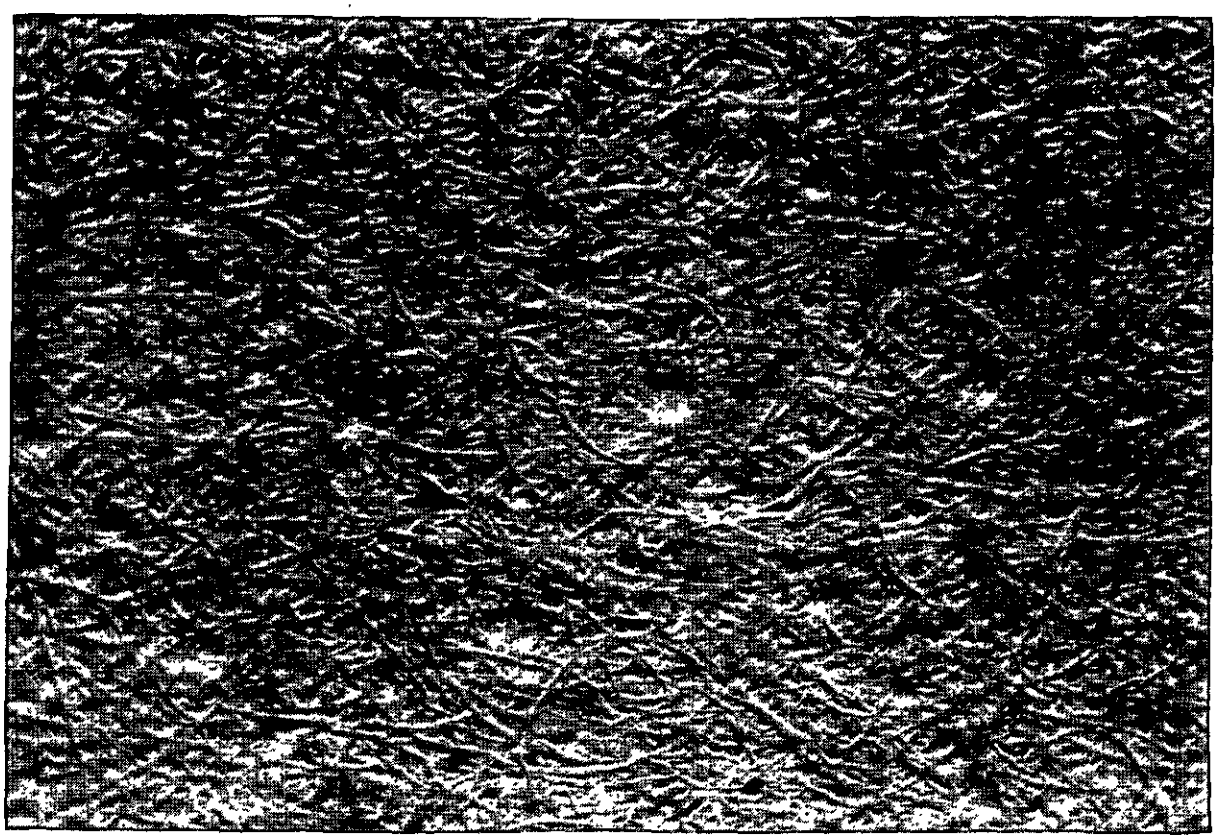


Figure 6 (Continued)

Run 5 Calendered (2.86 lb./ream, 600 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

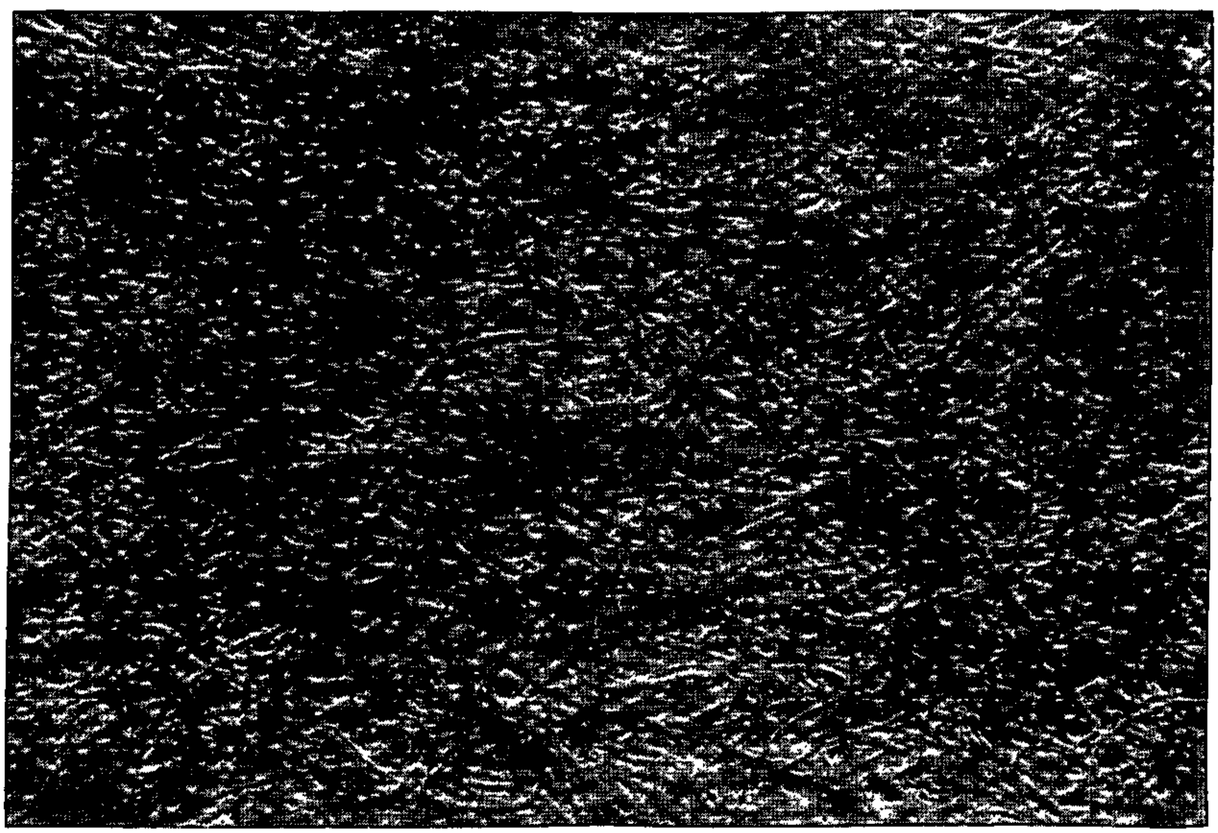


Figure 6 (Continued)

Run 6 Uncalendered (3.58 lb./ream, 700 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

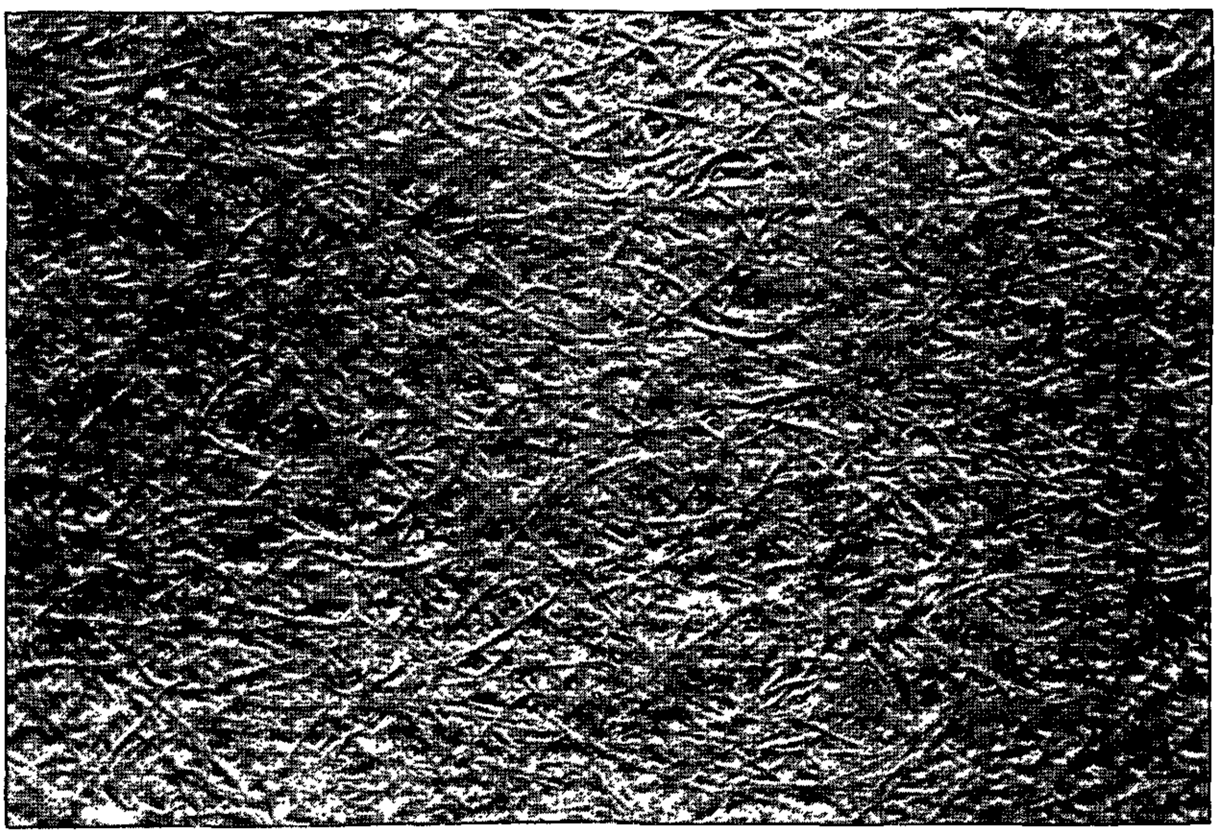


Figure 6 (Continued)

Run 6 Calendered (3.58 lb./ream, 700 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

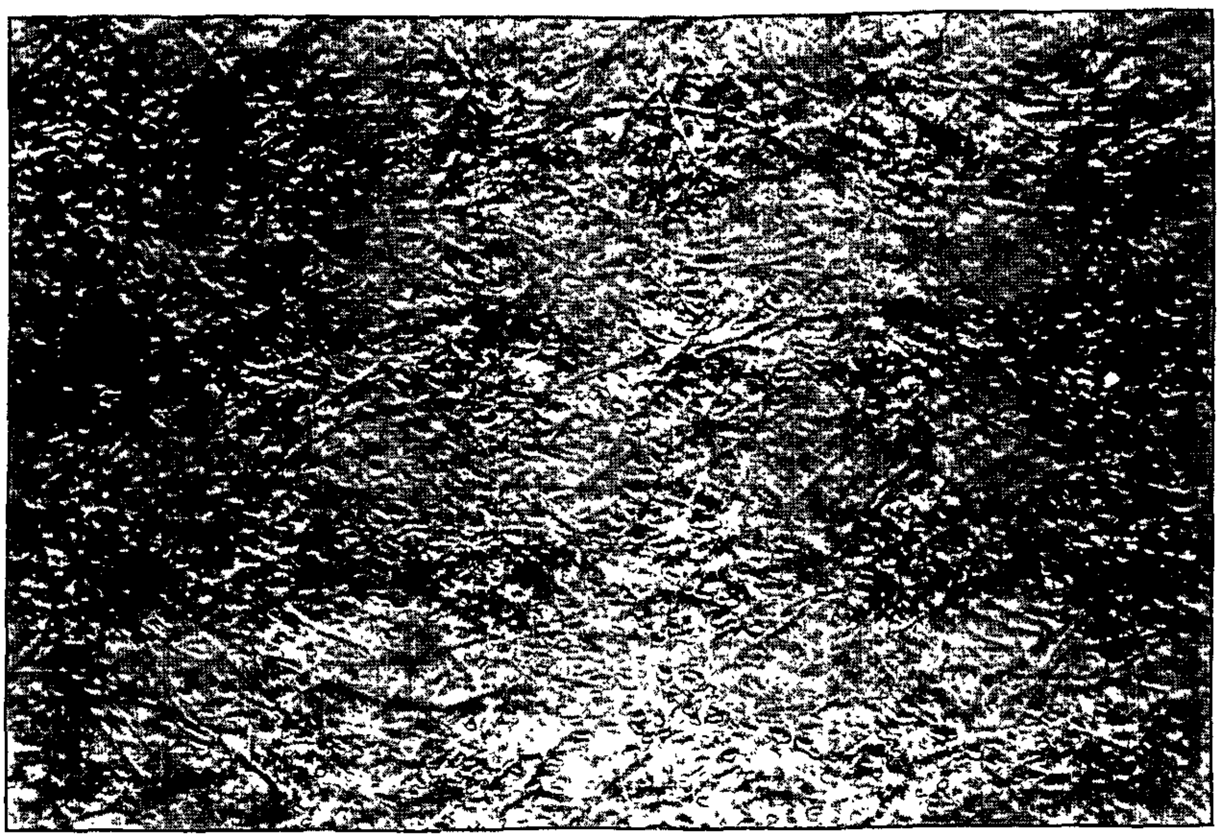


Figure 6 (Continued)

Run 7 Uncalendered (4.13 lb./ream, 800 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

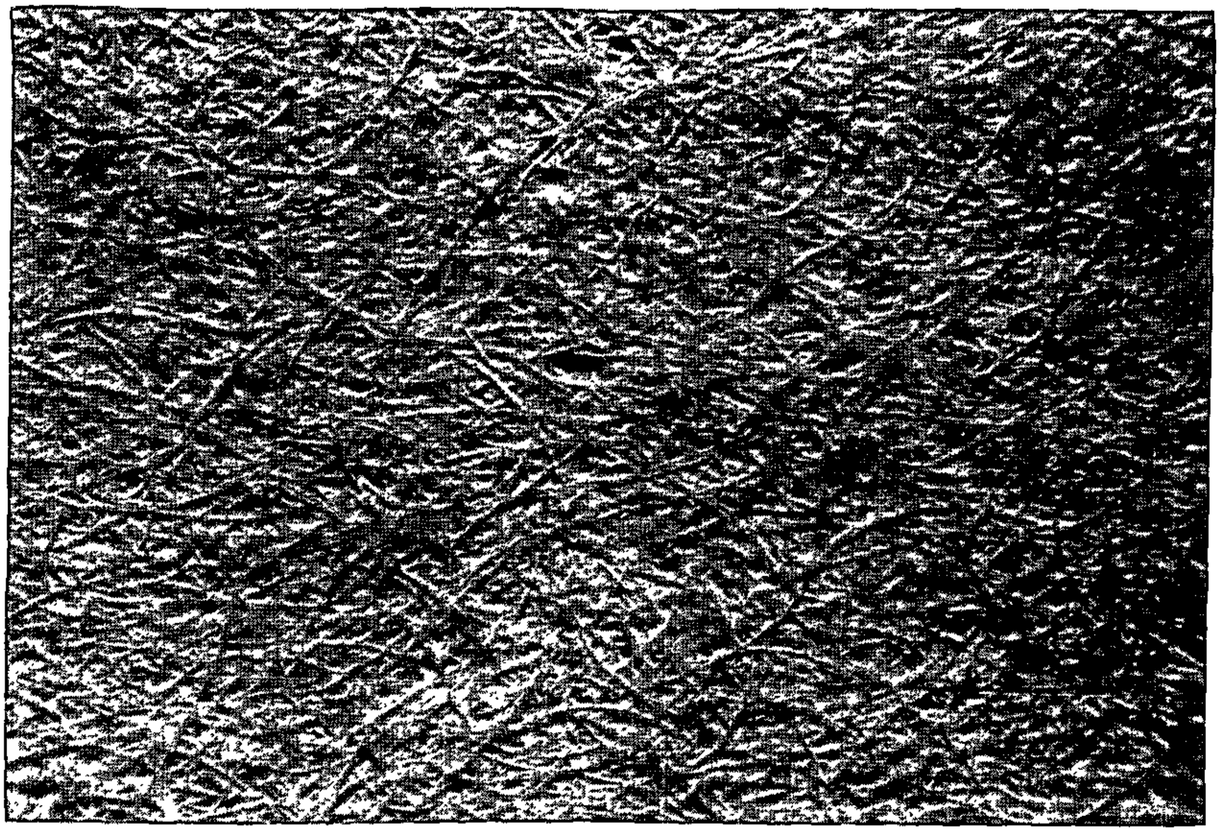


Figure 6 (Continued)

Run 7 Calendered (4.13 lb./ream, 800 ft./min.)
20X Oblique Illumination
(Angle of Incidence=85°)

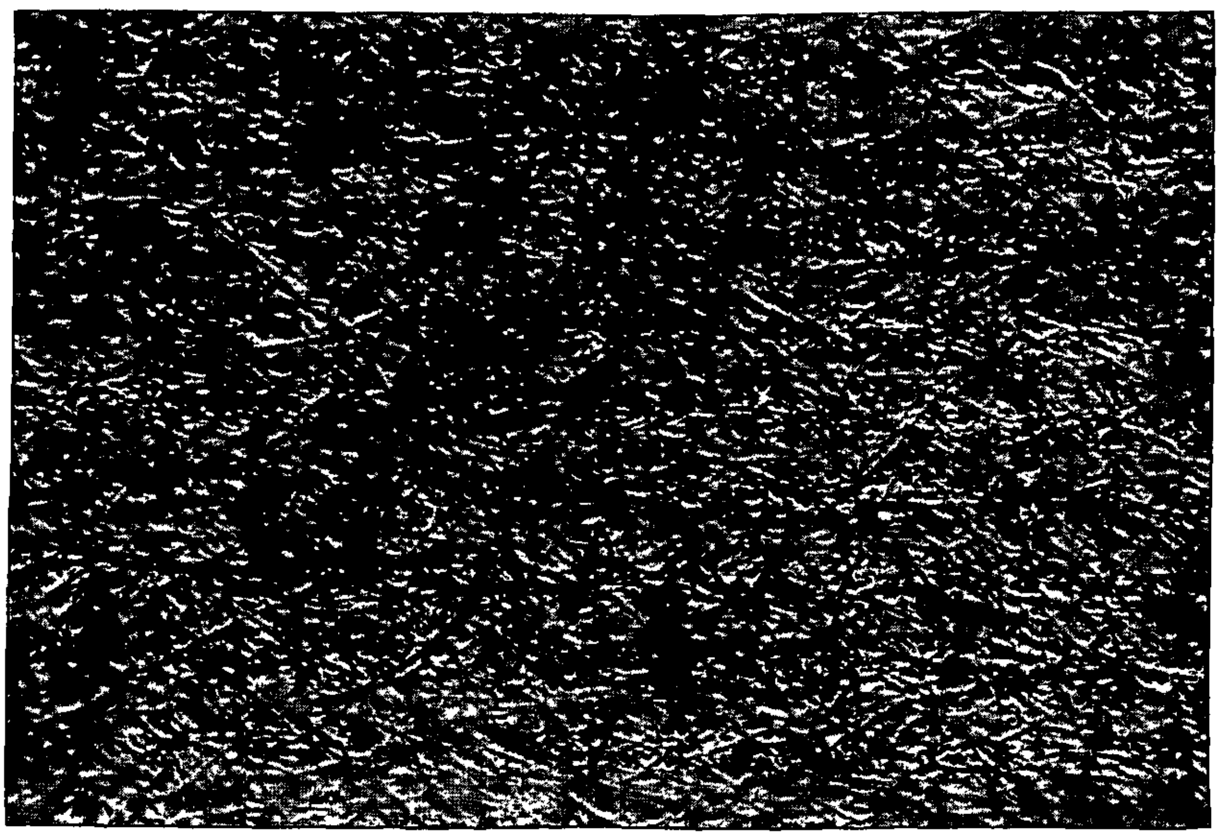
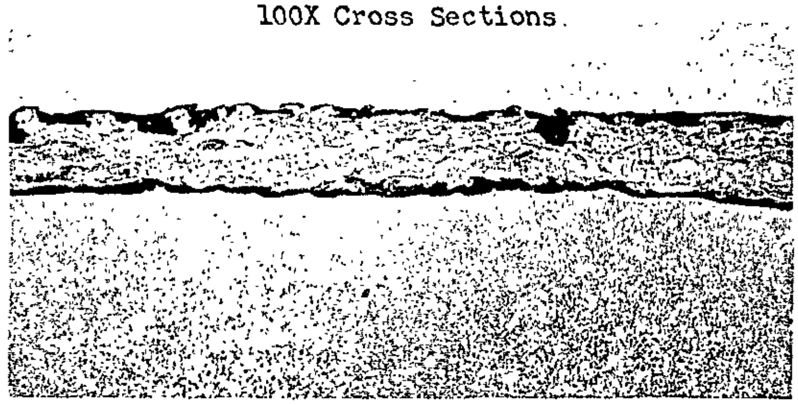
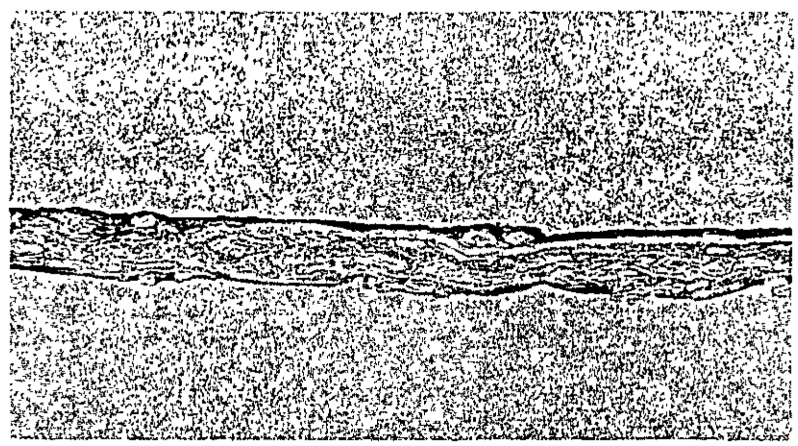


Figure 7

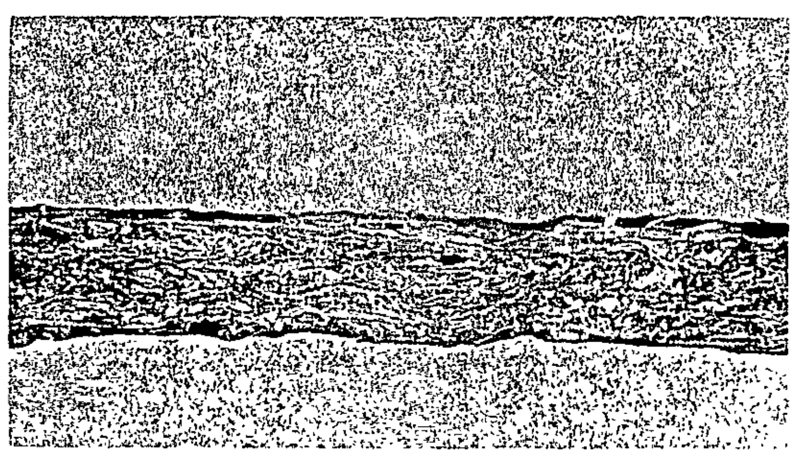
100X Cross Sections



100X Cross Section, Trailing Blade Coated Paper, Run 6



100X Cross Section, Time Magazine (inside page)



100X Cross Section, On-Machine Coated Esparto according to the cross section photographs it is believed that this appearance of roughness is due to a fold-over of the coating which took place during microtome sectioning. It was found that the coated paper was difficult to cross section satisfactorily.

The Chapman smoothness tests which were made with both soft (rubber) and hard (glass) backings and at three different pressures indicated that the experimentally coated paper (using the trailing blade) was smoother than one commercially coated paper and an uncoated commercial book paper (Table III). As might be expected in the case of a lightweight paper, the smoothness values ran appreciably higher when tested against a glass backing. The smoothness values also ran appreciably higher as the test pressure was increased (Fig. 8). The application of clay coating with the trailing blade improved the smoothness of the paper. Variations in the blade pressure and speed of coating had but little effect on the Chapman smoothness.

The effect of calendering was pronounced for both coated and uncoated paper. The calendered sheets were definitely less varied in surface characteristics.

The lowered smoothness as the trailing blade pressure was reduced and as the speed was increased may have been due to vibrations developed or to the effect of drying the heavier coatings.

The clay coatings applied with the trailing blade improved the gloss of the papers (Table III). However, the maximum gloss achieved by calendering did not come up to that attained with the commercially coated and supercalendered paper.

TABLE II

SURFACE QUALITY OF TRAILING BLADE COATINGS

		Coat Weight lb./ream	Chapman Smoothness, %: 177 p.s.i. Glass	177 p.s.i. Rubber	354 p.s.i. Glass	354 p.s.i. Rubber	708 p.s.i. Glass	708 p.s.i. Rubber	B. & L. Gloss	Print Quality, %[1]: 10 kg./cm. 0.8 Micron	10 kg./cm. 2.2 Micron	40 kg./cm. 0.8 Micron	40 kg./cm. 2.2 Micron
Base Stock	Uncalendered	--	4	9	7	12	11	18	7.4	19	59	40	78
	Calendered	--	10	13	14	19	20	25	14.	36	72	49	82
Run 1	Uncalendered	3.97	6	8	9	13	14	21	9.0	19	62	46	89
	Calendered	3.97	10	15	16	22	24	33	25.	43	92	71	91
Run 2	Uncalendered	3.75	5	8	8	13	13	21	9.4	20	61	46	89
	Calendered	3.75	9	15	15	21	23	32	26.	37	84	62	92
Run 3	Uncalendered	2.85	5	8	8	12	15	23	12.0	22	56	53	91
	Calendered	2.85	11	16	18	24	30	38	32.	40	89	73	93
Run 4	Uncalendered	2.97	5	7	8	12	14	21	10.0	21	62	47	90
	Calendered	2.97	9	15	15	24	25	37	27.	44	83	75	92
Run 5	Uncalendered	2.86	5	7	8	12	14	22	9.6	22	54	51	90
	Calendered	2.86	10	16	17	25	27	38	30.	45	84	74	92
Run 6	Uncalendered	3.58	5	7	8	11	14	20	9.7	21	54	51	91
	Calendered	3.58	12	18	18	27	28	42	32.	46	87	76	93
Run 7	Uncalendered	4.13	5	7	8	12	13	22	9.8	20	65	50	91
	Calendered	4.13	10	17	16	26	25	41	29.	39	82	73	92
Control A (Coated)	Uncalendered	--	3	5	6	8	9	16	8.5	(27)[2]	--	--	(79)[3]
	Calendered	--	10	10	16	34	26	51	53.9	(66)[2]	--	--	(94)[3]
Control B (Uncoated)	Uncalendered	--	5	8	8	12	12	18	4.9	(31)[2]	--	--	(72)[3]
	Calendered	--	6	12	9	18	16	27	24.2	(49)[2]	--	--	(96)[3]

Controls A and B are commercial papers from different manufacturers. Values quoted are for felt side only.

[1]Printed with proofing ink except as noted below for Control A and Control B. $(100 - \frac{\text{Reflectance of print}}{\text{Reflectance of paper}} \times 100)$

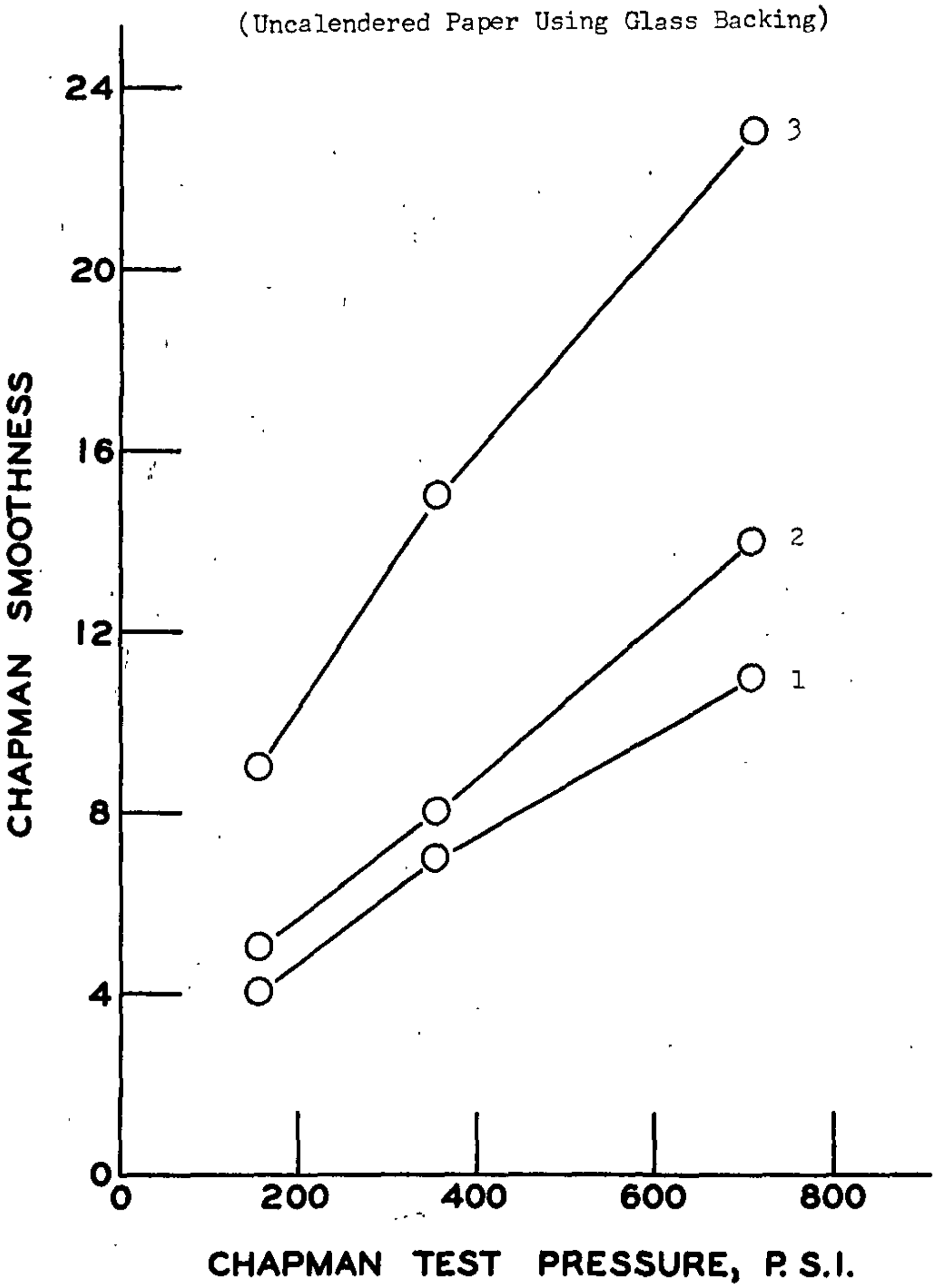
[2]Printed at 25 kg./in. with 0.8 micron film proofing ink.

[3]Printed at 25 kg./in. with 2.2 micron film No. 2 tack ink.

Figure 8

TRAILING BLADE COATED PAPER
CHAPMAN SMOOTHNESS
TEST PRESSURE

(Uncalendered Paper Using Glass Backing)



1. Uncalendered base paper

2. Uncalendered 2.97 lb./ream coating

3. Uncalendered 3.75 lb./ream coating

The Larocque print quality was tested at two levels of ink film thickness and at two levels of printing pressure. The lower (0.8 micron) ink thickness gave greater differences in print quality (Figure 9). The experimentally coated and calendered paper showed print quality very close to that of the commercially coated and supercalendered paper realizing the difference in the test procedures used.

The appearance of the Larocque print quality test specimens may be observed in Figure 10. They appear to be free of any pattern which might be attributed to the coating process.

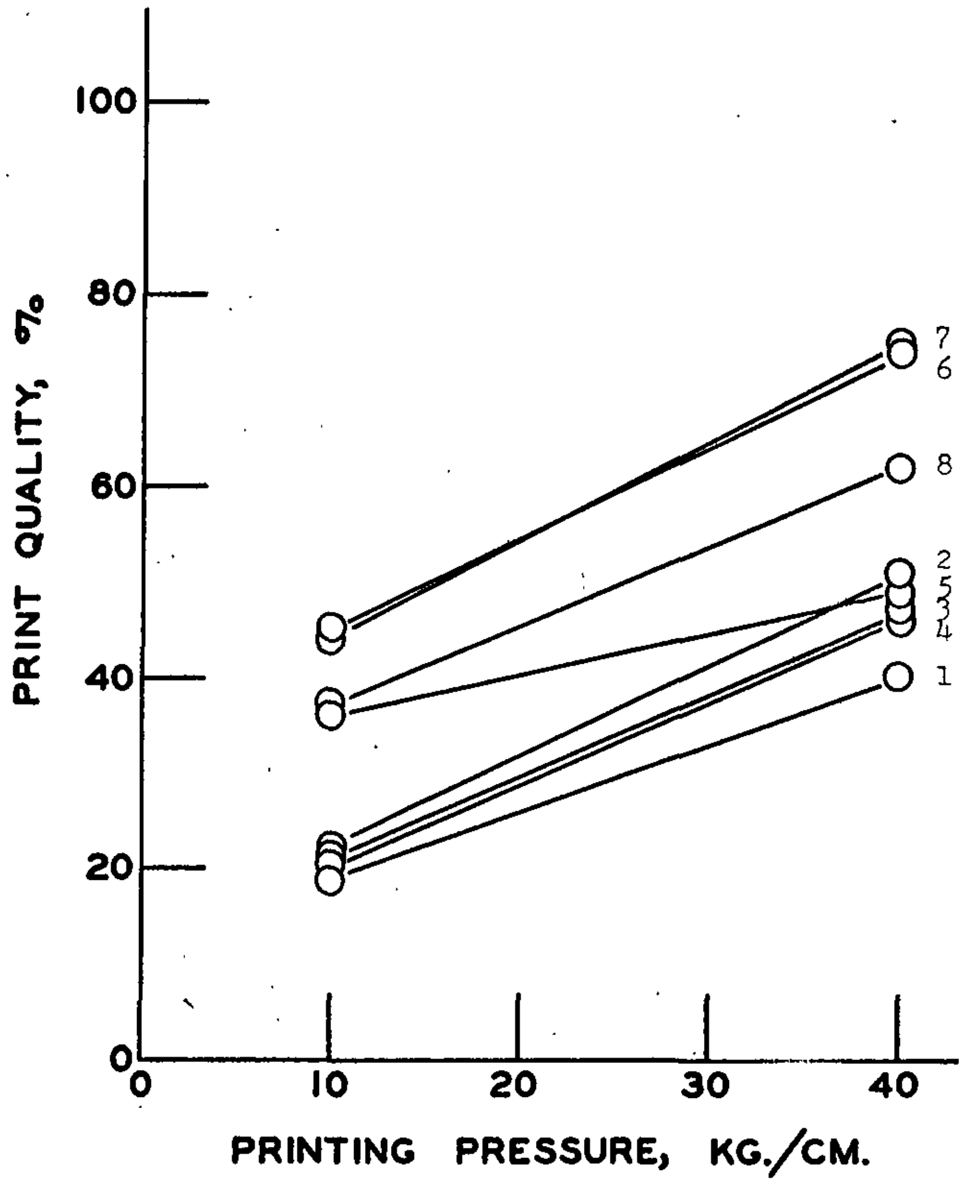
The rate of shear encountered in coating with the trailing blade may be estimated roughly by dividing the speed at which the coating is applied expressed in centimeters per second by the gap in centimeters. The maximum speed of coating achieved in this series of tests was only 800 feet per minute whereas the maximum speed which can be used is about 2,400 feet per minute. The thickness of the dry coating is in the range of 12 to 15 microns according to cross section studies. Without information on the density of the coating as applied, let us assume a thickness of wet coating of 20 microns as being reasonable. Using these assumptions, we may predict that the rate of shear at 800 feet per minute would be 12 million reciprocal seconds and at 2400 feet per minute it would be 36 million reciprocal seconds.

fv/bl

Figure 9

TRAILING BLADE COATINGS

EFFECT OF PRINTING PRESSURE ON PRINT QUALITY



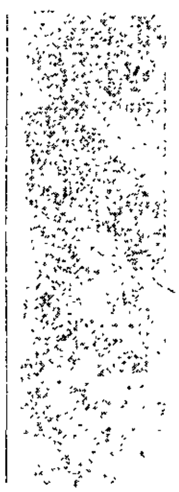
Uncalendered	Calendered
1. Base paper, 0.8 micron film	5. Base paper, 2.2 micron film
2. 2.86 lb./ream, 0.8 micron film	6. 2.86 lb./ream, 2.2 micron film
3. 2.97 lb./ream coat, 0.8 micron film	7. 2.97 lb./ream, 2.2 micron film
4. 3.75 lb./ream, 0.8 micron film	8. 3.75 lb./ream, 2.2 micron film

Figure 10

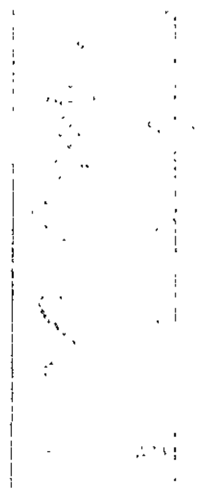
LAROCQUE PRINT QUALITY

I. Uncalendered Paper

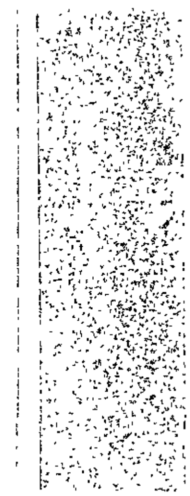
A. 0.8 micron ink film, 10 kg./cm. pressure



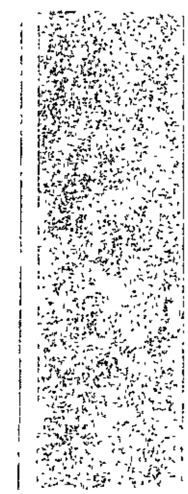
Uncoated
Paper



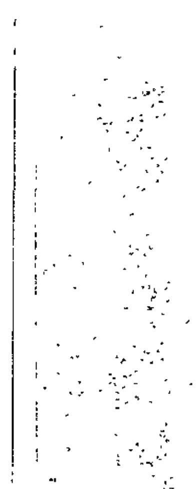
Run 2
(3.75 lb./ream
600 ft./min.)



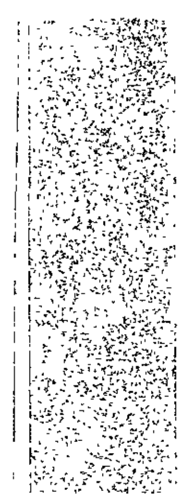
Run 4
(2.97 lb./ream
600 ft./min.)



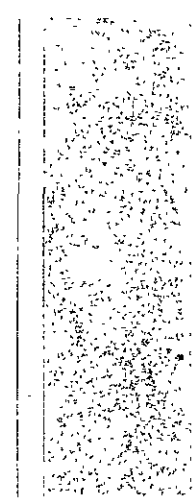
Run 5
(2.86 lb./ream
600 ft./min.)



Run 3
(2.85 lb./ream
200 ft./min.)



Run 6
(3.58 lb./ream
700 ft./min.)



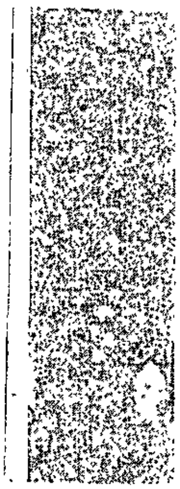
Run 7
(4.13 lb./ream
800 ft./min.)

Figure 10 (Continued)

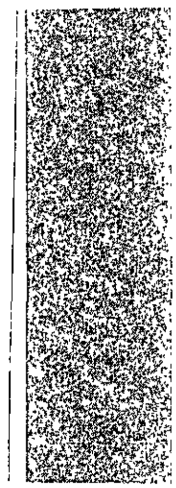
LAROQUE PRINT QUALITY

I. Uncalendered Paper

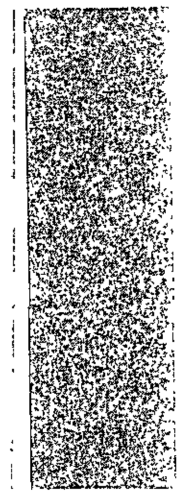
B. 0.8 micron ink film, 40 kg./cm. pressure



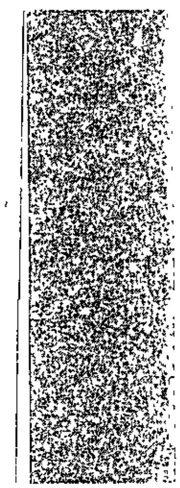
Uncoated Paper



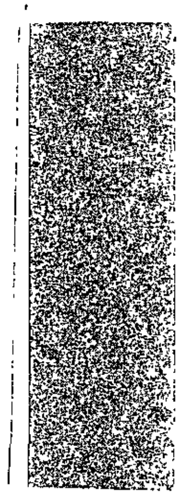
Run 2 (3.75 lb./ream 600 ft./min.)



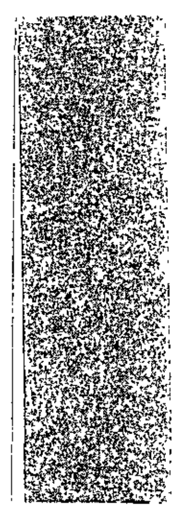
Run 4 (2.97 lb./ream 600 ft./min.)



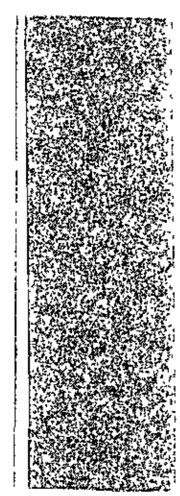
Run 5 (2.86 lb./ream 600 ft./min.)



Run 3 (2.85 lb./ream 200 ft./min.)



Run 6 (3.58 lb./ream 700 ft./min.)



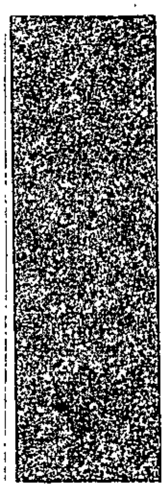
Run 7 (4.13 lb./ream 800 ft./min.)

Figure 10 (Continued)

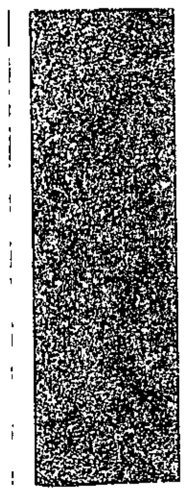
LAROCQUE PRINT QUALITY

I. Uncalendered Paper

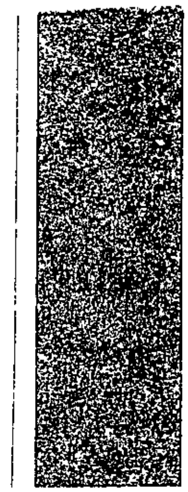
C. 2.2 micron ink film, 10 kg./cm. pressure



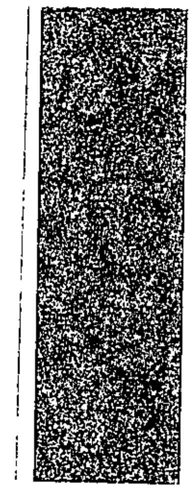
Uncoated
Paper



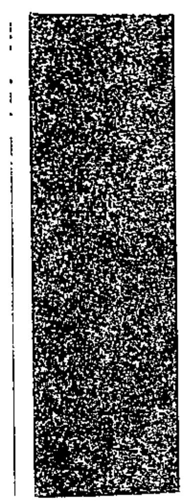
Run 2
(3.75 lb./ream
600 ft./min.)



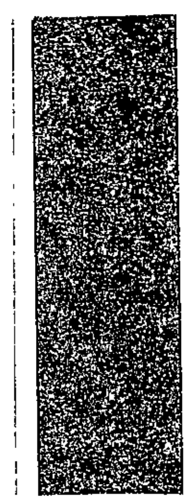
Run 4
(2.97 lb./ream
600 ft./min.)



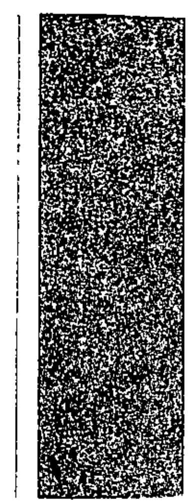
Run 5
(2.86 lb./ream
600 ft./min.)



Run 3
(2.85 lb./ream
200 ft./min.)



Run 6
(3.58 lb./ream
700 ft./min.)



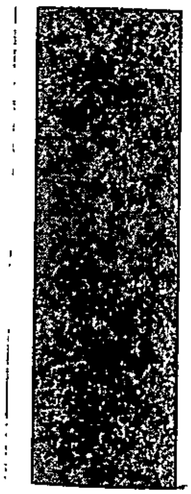
Run 7
(4.13 lb./ream
800 ft./min.)

Figure 10 (Continued)

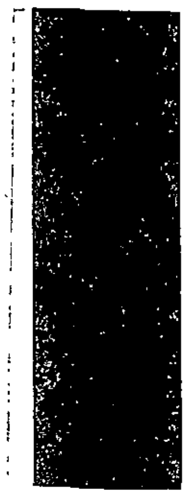
LAROCQUE PRINT QUALITY

I. Uncalendered Paper

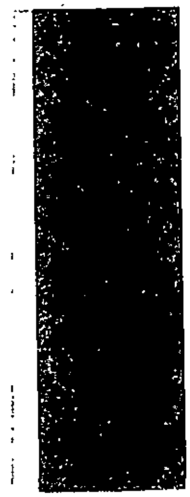
D. 2.2 micron ink film, 40 kg./cm. pressure



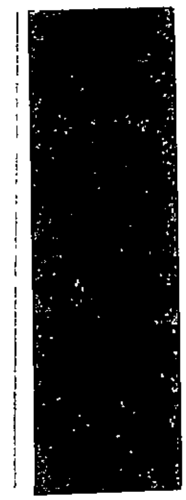
Uncoated
Paper



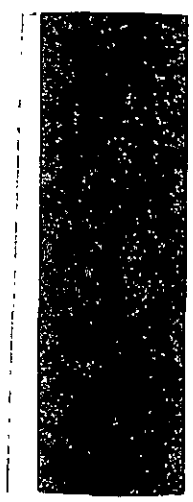
Run 2
(3.75 lb./ream
600 ft./min.)



Run 4
(2.97 lb./ream
600 ft./min.)

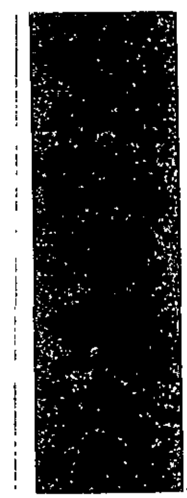


Run 5
(2.86 lb./ream
600 ft./min.)



Run 3
(2.85 lb./ream
200 ft./min.)

Run 6
(3.58 lb./ream
700 ft./min.)



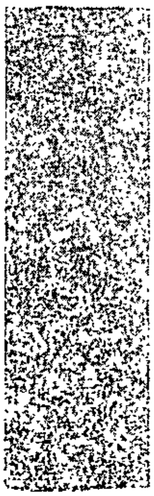
Run 7
(4.13 lb./ream
800 ft./min.)

Figure 10 (Continued)

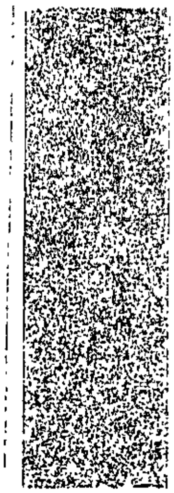
LAROCQUE PRINT QUALITY

II. Calendered Paper

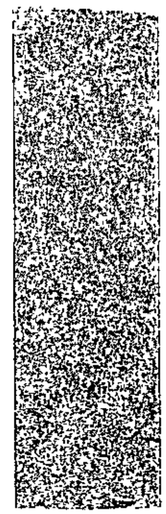
A. 0.8 micron ink film, 10 kg./cm. pressure



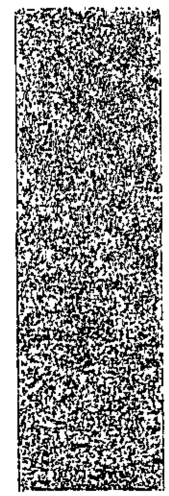
Uncoated
Paper



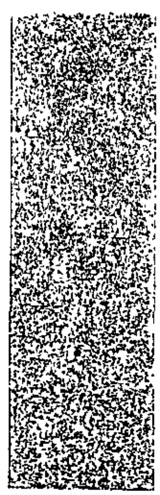
Run 2
(3.75 lb./ream
600 ft./min.)



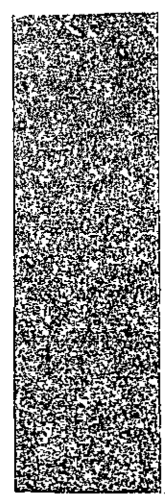
Run 4
(2.97 lb./ream
600 ft./min.)



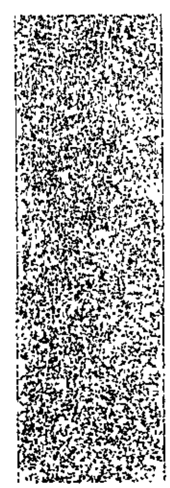
Run 5
(2.86 lb./ream
600 ft./min.)



Run 3
(2.85 lb./ream
200 ft./min.)



Run 6
(3.58 lb./ream
700 ft./min.)



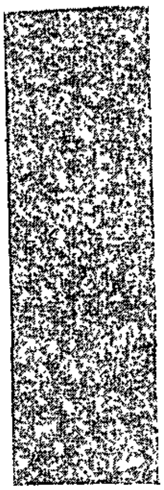
Run 7
(4.13 lb./ream
800 ft./min.)

Figure 10 (Continued)

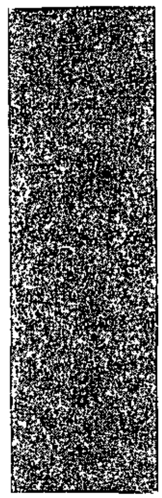
LAROCQUE PRINT QUALITY

II. Calendered Paper

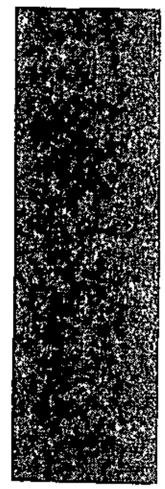
B. 0.8 micron ink film, 40 kg./cm. pressure



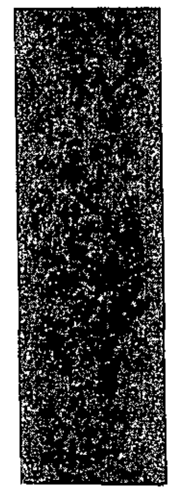
Uncoated
Paper



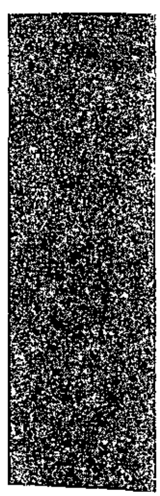
Run 2
(3.75 lb./ream
600 ft./min.)



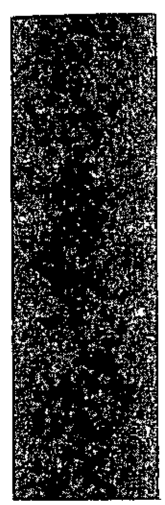
Run 4
(2.97 lb./ream
600 ft./min.)



Run 5
(2.86 lb./ream
600 ft./min.)



Run 3
(2.85 lb./ream
200 ft./min.)



Run 6
(3.58 lb./ream
700 ft./min.)

Run 7
(4.13 lb./ream
800 ft./min.)

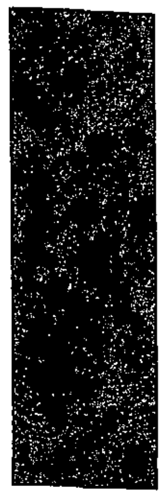
Figure 10 (Continued)

LAROCQUE PRINT QUALITY

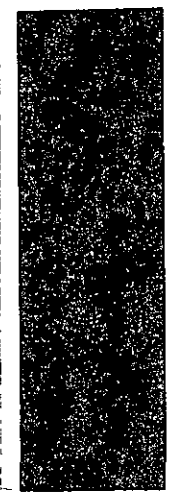
II. Calendered Paper

C. 2.2 micron ink film, 10 kg./cm. pressure

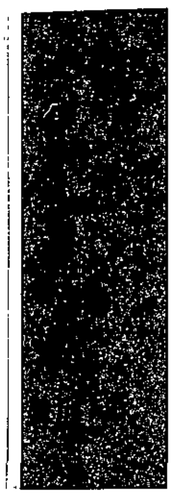
Uncoated Paper



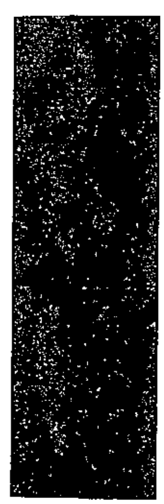
Run 2 (3.75 lb./ream 600 ft./min.)



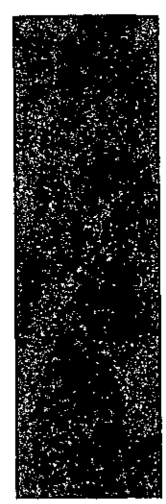
Run 4 (2.97 lb./ream 600 ft./min.)



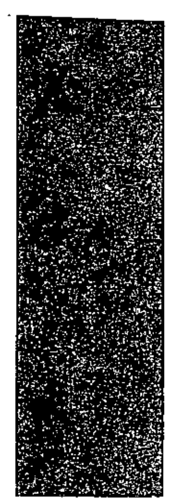
Run 5 (2.86 lb./ream 600 ft./min.)



Run 3 (2.85 lb./ream 200 ft./min.)



Run 6 (3.58 lb./ream 700 ft./min.)



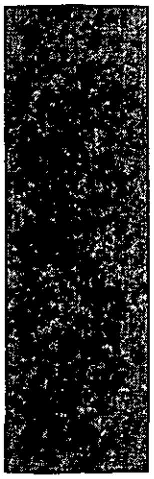
Run 7 (4.13 lb./ream 800 ft./min.)

Figure 10 (Continued)

LAROCQUE PRINT QUALITY

II. Calendered Paper

D. 2.2 micron ink film, 40 kg./cm. pressure



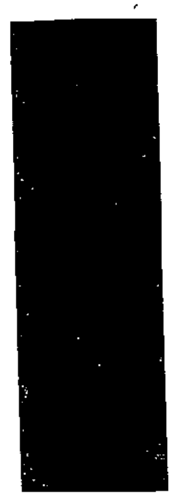
Uncoated Paper

Run 2
(3.75 lb./ream
600 ft./min.)

Run 4
(2.97 lb./ream
600 ft./min.)

Run 5
(2.86 lb./ream
600 ft./min.)

Run 3
(2.85 lb./ream
200 ft./min.)



Run 6
(3.58 lb./ream
700 ft./min.)

Run 7
(4.13 lb./ream
800 ft./min.)

REFERENCES CITED

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2. Editors, Paper Trade Journal 143, no. 25, p. 26, June 22, 1959.

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5. Sturken, R. C. and Egan, L. W. Tappi 36, no. 6, p. 38A, June, 1959.

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10. TAPPI Standard T 480 m-51.

11. Larocque, G.; Axelrol, B. and Clark, S. Pulp and Paper Magazine of Canada 52, no. 3, 166-174, Convention Issue 1951.

PROJECT REPORT FORM

PROJECT NO. 1956
COOPERATOR I.P.C.
REPORT NO. 29
DATE June 22, 1959
NOTE BOOK 1679, 1718, 1819
PAGE 137-160, 53 TO 58, 19-41
SIGNED Wallace E. Voeks

Wallace E. Voeks

Frans Vaurio
Frans Vaurio

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STUDY OF COATING COLOR PREPARATION

EVALUATION OF LABORATORY DISPERSING EQUIPMENT

INTRODUCTION

There is little factual information available in the literature to guide one in selecting equipment for color preparation for paper coating. The recent trend toward greater activity in paper coating has accentuated the problem.

Most pigments such as clay, titanium dioxide, satin white, zinc oxide, and calcium carbonate are prepared and sold with a fine particle size. However, the dispersion of these pigments in the coating mix, especially at high solids, is often a problem. The introduction of the trailing blade type coater has led to the need for better means for color preparation at high solids.

According to the literature and through private conversation, high solids coatings are being produced with various types of dispersing equipment such as rotating disk, rotating saw-type impeller, spiral ribbon mixers, multi-roll paint or ink mills, heavy duty Z-bar or sigma blade mixers, and impact mills.

The efficiency of a dispersing unit may, to a certain respect, be predicted by the ability of the unit to do work on the coating. This has been brought out by studies in the field of surface chemistry where it has been shown that the size of particles in a dispersion of solid particles in a liquid is a function of the amount of work which has been used in preparing the dispersion.

Thus it may be readily predicted that slow-moving equipment will require a proportionately longer processing time than fast impellers or impact mixers. The slow-moving sigma blade mixers operate best at very high viscosity with dough-like mixtures since all the shear is produced within the mixture. The rotating disk type mixer utilizes the high shear of a relatively high viscosity mixture. The saw-blade type mixer apparently increases the shear by introducing a forced change of direction of the agitated mixture and is believed effective at lower viscosities than the plain disk. The impact mill imparts a high velocity to the particles of the mixture and causes them to impact a stator to cause very high shear rates. Its operation is limited to lower viscosity systems.

The tendency for inclusion of air is undesirable in some applications and may be a factor in coming to a decision in selecting a dispersing unit. The sigma blade and top entrant impeller type units are especially prone to introduce air or foam into a coating. In some cases, the viscosity may be so low that air entrainment is not a problem. In other cases it has been found that the quality of a coating may be improved by providing a coating color with minimum foam or entrapped air.

A study was conducted to determine the relative effectiveness of various methods of dispersing coating color. The devices used for dispersing a clay slip of approximately 70 per cent total solids were a Kady Mill, Lightnin' mixer, Homo-Mixer, Baker Perkins mixer, Ball Mill, and a Charlotte Colloid Mill. Unfortunately, we did not have available the Cowles type or serrated disk disperser which has been found by some to be very useful in preparing coating color mixes.

The effect of the method of dispersing with respect to clay particle size will be studied with an electron microscope and covered in a later report.

This report will serve to record the dispersing conditions and their effects on the viscosity of the prepared clay slip.

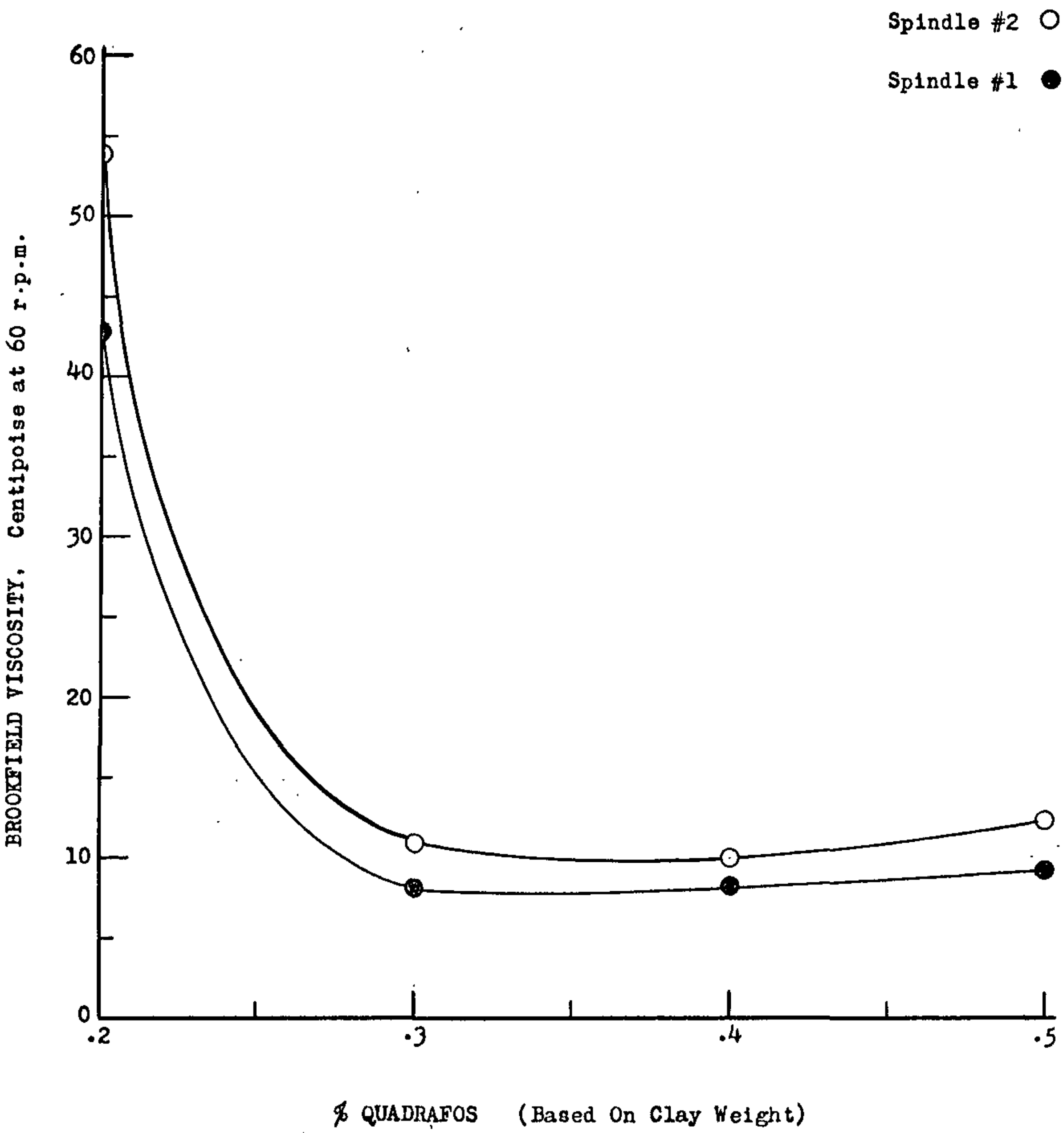
PROCEDURE

The amounts of clay, Quadrafos and water for the formulations were combined to give a total solids content of approximately 70 per cent. The "Premax" clay used was obtained from Combined Locks.

The amount of Quadrafos added to the formulations was .35 per cent based on the clay weight. A study was made of the effect of Quadrafos on the dispersing of clay slips with respect to viscosity. The viscosity of a 50 per cent total solids clay slip fell to a minimum near the addition of .3 per cent Quadrafos based on clay weight (see Figure 1). The viscosity appeared to rise after the addition of .4 per cent Quadrafos based on clay weight.

Figure 1

THE RELATIONSHIP BETWEEN VISCOSITY
AND PERCENTAGE OF QUADRAFOS FOR
CLAY SLIPS OF 50% TOTAL SOLIDS



The mixing conditions provided for each formulation listed in Table I are as follows:

Formulation 1819-23; Ball Mill

Material	Parts by Weight, g.
"Premax" clay	2000
Quadrafos	7
Water	860

A one-gallon Abbe Ball Mill crock was used with the Paul Abbe Company Ball Mill rotator set at a speed of 48 r.p.m. The crock was one-quarter filled with stones of assorted sizes and the above ingredients added directly to the crock. The formulation was blended for two hours.

Formulation 1679-160; Lightnin' Mixer

Material	Parts by Weight, g.
"Premax" clay	4667
Quadrafos	16
Water	2000

A Model V Lightnin' mixer with double propeller was used to disperse the clay slip. The water and Quadrafos were mixed and the clay added slowly with mixing. A General Radio Company Variac at a setting of 70 was used to control the mixer speed. It took 30 minutes to add the clay. The formulation was then mixed an additional 30 minutes.

Formulation 1819-21; Baker Perkins Mixer

Material	Parts by Weight, g.
"Premax" clay	5000
Quadrafos	17.5
Water	2150

TABLE I

Viscosity of Clay Slips Dispersed Under Various Conditions

Formulation	Dispersing Device	Total Mixing Time, Minutes	Solids[1], %	Viscosity, cp.[2] Spindle #1	Spindle #2
1819-23	Ball Mill	120	69.7	100+	112.5
1679-160	Lightnin' mixer	60	70.2	96	106
1819-21	Baker Perkins	120	70.1	92	99
1819-27	Baker Perkins	120	70.8	88	92.5
1819-25	Homo-Mixer	45	69.9	81	86
1819-39	Charlotte Colloid Mill	2[a]	70.0	66.1	70
1679-153-1	Kady Mill Low Speed	16	69.6	72	82.5
1679-153-2	"	21	69.6	72	77.5
1679-153-3	"	26	69.6	69.5	76
1679-153-4	"	31	69.6	68	74
1679-153-5	"	36	69.6	70.5	76
1679-153-6	"	41	69.6	61.5	66
1679-156-1	Kady Mill High Speed	39	70.1	64	67
1679-156-2	"	45	70.2	54.5	57.5
1679-156-3	"	50	69.9[b]	54.5	59.0
1679-156-4	"	55	69.9+[c]	55	60
1679-156-5	"	60	69.9+[c]	57.5	62.5
1679-156-6	"	65	70.0	(Sample Lost)	

NOTES:

[a]It took only a couple minutes to pass the formulation through the colloid mill. Time to prepare the formulation is not counted.

[b]A few minutes before this mixing time the formulation was diluted as described in the mixing procedure for this formulation.

[c]The solids content of these two formulations was not determined.

[1]These are the solids content values of the formulations as mixed. All of the formulations were reduced to the solids content of 69.6% before determining viscosity.

[2]Brookfield Model LV viscosity at 60 r.p.m. of the formulations at 69.6% solids.

A three-gallon capacity Baker Perkins mixer was used to disperse the clay slip. The clay and Quadrafos were placed in the Baker Perkins mixer. The mixer was run for a few minutes to mix the clay and Quadrafos and to break down some of the larger lumps. Water was added slowly with mixing until about 1900 g. of water had been added. The formulation at this point contained approximately 72.5 per cent solids. This portion was mixed for 1-1/2 hours. The remaining water was then added slowly and the formulation mixed an additional 30 minutes.

Formulation 1819-27; Baker Perkins Mixer

Material	Parts by Weight, g.
"Premax" clay	5000
Quadrafos	17.5
Water	2150

A three-gallon capacity Baker Perkins mixer was used to disperse the clay slip. The clay and Quadrafos was placed in the Baker Perkins mixer and the mixer was run for a few minutes to mix the clay and Quadrafos and to break down some of the larger lumps. Water was added slowly with mixing until about 1530 g. of water had been added. We attempted to achieve more shearing action with this Baker Perkins mix as compared to the previous (1819-21). The formulation in the Baker Perkins mixer at this point contained approximately 76.6 per cent solids. This portion was mixed for 1-1/2 hours. The remaining water was then slowly added and the formulation mixed an additional 30 minutes.

Formulation 1819-25; Homo-Mixer

Material	Parts by Weight, g.
"Premax" clay	3000
Quadrafos	10.5
Water	1290

A Lamb Electric Company 1/4 h.p. Homogeneous mixer was used to disperse the clay slip. The Quadrafos and water were placed together and the clay was added slowly with mixing. The addition of clay required about 25 minutes. After all of the clay had been added, the formulation was mixed an additional 20 minutes.

Formulation 1819-39; Charlotte Colloid Mill

Formulation 1819-23 which had been ball-milled appeared to have the highest viscosity of the previous preparations. Therefore, it was decided to run a portion of that formulation through the Charlotte Colloid Mill.

A Model ND-1 Charlotte Colloid Mill was used to disperse the clay slip. Initially a gap of .005 inch was set between the rotor and stator of the mill. This close gap caused too much shear and the circuit overloaded and a fuse blew. This also occurred with gap settings of .010 and .015 inch. The gap was finally opened to its maximum of approximately .036 inch and the formulation flowed through the mill easily. One quart of the formulation was passed through the mill three times. This took only a few minutes.

Formulations 1679-153-1 through 1679-153-6;
Kady Mill, Low Speed

Material	Parts by Weight
"Premax" clay	110 lb.
Quadrafos	175 g.
Water	47 lb.

A Model O Kady Mill was used to disperse the clay slip. The mill had a close-spaced rotor, small size upper impeller, and was set at its low speed setting of approximately 3000 r.p.m. The water and Quadrafos were placed in the mill and the clay added as rapidly as possible without overloading the circuit. All ingredients were added after 11 minutes. The current requirements for the 20 h.p. electric motor on the Kady Mill stayed below 60 amperes. After every five minutes for 30 minutes thereafter, a sample of the formulation was drawn from the spigot on the bottom of the Kady Mill. These samples were designated 1679-153-1, 1679-153-2, 1679-153-3, 1679-153-4, 1679-153-5, and 1679-153-6 in that order of withdrawal.

Formulations 1679-156-1 through 1679-156-6;
Kady Mill, High Speed

Material	Parts by Weight
"Premax" clay	110 lb.
Quadrafos	175 g.
Water	47 lb.

A Model O Kady Mill was used to disperse the clay slip. The mill had a close-spaced rotor, small size upper impeller, and was set at its high speed setting of approximately 6700 r.p.m. The water and Quadrafos were placed in the mill and the clay added as rapidly as possible without overloading the circuit. Difficulty was encountered in the addition of the last 1/2 to 1 pound of clay. The heat of mixing dissipates some water. A small amount of water was added and the remainder of the clay was added for a total clay addition time of 34 minutes. Every five minutes for 30 minutes thereafter, a sample of the formulation was drawn from the spigot on the bottom of the Kady Mill. The samples were designated 1679-156-1, 1679-156-2, 1679-156-3, 1679-156-4, 1679-156-5, and 1679-156-6 in that order of withdrawal. Amperage requirements began exceeding the safety limits of the motor as the formulation was being mixed and a small amount of water was added between samples 1679-156-2 and 1679-156-3, which lowered the solids content from 70.2 per cent to 69.9 per cent.

Interest in the capabilities of the Kady Mill prompted a preliminary investigation. The following formulations were dispersed with the Model O Kady Mill and the current requirements of the 20 h.p. electric motor were observed using a type AD-6 G.E. A-C ampere meter.

	Parts by Weight, lb.			
Material	Formulation 1679-137	Formulation 1679-152	Formulation 1679-156	Formulation 1718-55
"Premax" clay	109.5	110.00	110.00	
Quadrafos	.6	.39	.39	
Water	47.8	47.00	47.00	45.0
TiO_2 (Titanox RA-50)				26.0
$CaCO_3$ (Purecal M)				79.0
Calgon T				1.5
Kady Mill Speed:	(3000 r.p.m.)	(3000 r.p.m.)	(6700 r.p.m.)	(3000 r.p.m.)

The water and dispersing agent were placed in the Kady Mill and the solids added with mixing. At various stages samples were taken for solids content determination or the solids content was calculated from the amount of materials in the formulation at the time. The amperage requirements of the Kady Mill motor for various solids contents of the above formulations are listed in Table II.

TABLE II

Kady Mill Amperage Requirements for Dispersing Various Slips

	Solids, %			
Amperes	Formulation 1819-55	Formulation 1679-137	Formulation 1679-152	Formulation 1679-156
35			69.6	
36	61.4			
40	64.7			
53		69.1		
55	70.3			
56	70.3			
58		70.3		
60	69.9			
68		70.7		69.9
72		71.0		70.1
73				70.0
77				70.0
80				70.2

RESULTS AND OBSERVATIONS

From the results of the viscosities of the various type dispersed clay slips, it would appear that the Kady Mill does the most thorough job of dispersing the clay slip in the shortest time.

Following the Kady Mill in their decreasing order of effectiveness were the Charlotte Colloid Mill, Homo-Mixer, Baker Perkins Mixer, Lightnin' Mixer, and the Ball Mill. (This is not taking into account the time factors.)

An attempt will be made to study the clay particle size of the clay slips more quantitatively with the use of the electron microscope.

The Kady Mill appears to disperse the formulated slips satisfactorily at solids content levels up to 70 per cent without overloading the circuit. It can be seen that, especially at low speed settings, slips of around 71 per cent can be dispersed.

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