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Pigment Coating of Paper in the Laboratory a Comparison of Several Methods

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PIGMENT COATING OF PAPER IN THE LABORATORY

A COMPARISON OF SEVERAL METHODS

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ABSTRACT

Four Bench-type laboratory coaters were compared as to their pattern formation which influences the printability of the coated sheet.

The four Bench-type laboratory coaters used were Wire Wound Doctor Rods, Bird Film Applicators, Bench Trailing Blade Coater and the Martinson Coater.

A constant solids content coating color was used which consisted of 100 parts coating clay and 18 parts casein. A record of the viscosity of the coating slip was kept.

The coated sheets were evaluated by visual inspection, and photomicrographs were taken of the most characteristic patterns. Coat weight, reproducibility and smoothness values were also determined.

It was found that before supercalendering Bird Film Applicators gave the least pattern followed by Wire Wound Doctor Rods, Martinson Coater and Bench Type Trailing Blade Coater.

After supercalendering the patterns produced by all four devices looked similar. This was verified by the smoothness values, which all fell in the same range.

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INTRODUCTION

The constant growth of the coated paper industry has greatly increased the demand for methods and equipment useful in coating paper on a small scale by means of pilot size installations and by means of bench type laboratory equipment.

Both the pilot size and the bench type equipment are used to good advantage to evaluate the quality of established raw materials, to check the performance of newly developed products, and finally, to produce and evaluate new coating formulae and new grades of coated paper and paperboard. In general, the bench type laboratory coaters are suitable for sheet coating only, whereas the pilot size laboratory equipment permits web coating.

Pilot size equipment has the added advantage of making possible the evaluation of operational variables on a limited scale rather than on a production unit where machine time is extremely valuable.

Finally, pilot size equipment may be used to develop and evaluate new methods of coating color application, of drying, and possibly, of finishing.

Due to the demand for such type of equipment, it was decided to prepare a literature survey and to cover the

subject of coating of paper in the laboratory.

PILOT COATING PROCESSES

Current interest in small size coating machinery indicates a trend wherein extreme versatility is desired in order to handle a wide range of paper and paperboard, a variety of coating application processes, and a varied experimental capacity in the laboratory. In order to meet these requirements, more and more manufacturers are turning to pilot coating machinery of many sizes and designs.

A pilot coater, according to Casey (1), is a "small-scale replica of a commerical coating machine used in the plant." Today, however, a pilot coater is more than this. This definition must be expanded to include several commerical coating processes, ranging from simple size press coating to the new trailing blade coaters. By incorporating several different application methods into a single machine, one can gain all the benefits stated in the introduction of this survey, as well as the intangible benefits of training technical personnel and providing additional tools to improve the range and quality of service to the paper industry.

Instead of looking directly at some pilot coaters, the development of a "typical" pilot coater of unusual versatility will be discussed.

DEVELOPMENT OF A "TYPICAL" PILOT COATER

In a recent publication, Jones and Laughery (2) discussed some of the aspects of a pilot coating installation. One of the southern mills, with cylinder machine operation found it highly desirable, if not essential, to coat their papers and paperboard experimentally. They assigned the development of a pilot coater to their research division, which in turn conferred with a manufacturer of machinery. By pooling their efforts and coating knowledge, these two research divisions developed the following specifications for a pilot coater:

1. It must contain an air doctor because of its great versatility and its success in applying both protective and pigmented coatings.

2. It should be equipped with a blade coater because of its leveling action which provides an excellent printing surface, even though streaking and coat-weight limitations are known disadvantages.

3. A size press should be included because of its use for pre-treatment in coating.

4. Little time should be lost in changing from one coating process to another.

5. The speed of the coater should vary over the range of the operating speeds of cylinder machines.

6. Addition of other coating methods such as roll

and gravure coating should be readily adaptable to the basic frame.

7. The coater should trim up to 36 inches so that paperboard converters could evaluate experimentally coated samples in full scale converting operations.

8. A versatile drying system for different drying methods should be available.

9. Explosion proof electrical equipment should be installed for studies of applying functional coatings from solvent as well as water systems.

CROSSEET PILOT COATER

From the above specifications a pilot coater was built. The basic frame of the coating head was designed so that the variety of coating processes mentioned could be easily adapted to it.

In the air doctor operation, the color roll and color pan can be raised into operating position by means of two air cylinders attached to the bottom of this frame. The slow turning color roll applies an excess of coating color to the sheet, and the excess is removed by the air doctor.

A variation of a special trailing blade process can also be installed. In this, the rubber coated backing roll is locked into place in the frame and the coater is raised into operating position by the air-loaded cylinders as above. In this process, the amount of coating applied

may be controlled by varying the pressure in the coater head and by changing the pressure and the angle of the blade.

A magnetic metering bar coater, which is often used as a pre-coater in the paperboard industry, can also be easily adapted to the basic frame. This consists of a bar generally of .25 inch stock supported in a V notch, which cradles it rigidly and acts as a doctor to the bar as it rotates against the web travel.

Installation of a gate roll coater is easily accomplished by the addition of two metering rolls.

Offset or gravure coating processes can also be installed. In this coater, the depth of the etch will control the amount of coating applied. In direct gravure, the web will contact the etched roll directly; in offset the coating is transferred to a second roll and then to the paper.

A four roll reverse coater can also be added. This is best adapted for use in solvent coatings although it can be used for any type of coating. With this process it is possible to control film thickness within very close limits.

The coater itself is equipped with a line shaft drive powered by a 30 hp. a.c. motor. A magnetic clutch coupling between motor and line shaft allows variations in speed from 50 to 500 feet per minute. The bottom coater roll

is driven through a variable PIV drive by a right angle take-off of either clockwise or counterclockwise rotation. The speed of the drum driers, slot conveyor in the conventional dryer and top coater roll is controlled by a gear train fed by another take-off. A third take-off through a gear box drives the center roll of the calender stack and also provides power to the winder through an air loaded slipclutch.

The coater is also equipped with a gas-fired infrared unit, two drum driers, and a 45 foot double pass convection-type drier. A three roll calender stack, with the bottom and top rolls air loaded to 160 pounds per linear inch, and a single position rewind stand are also included.

The development of the above coater is just one illustration of the cause and effect which is primarily responsible for the continued advancement in the coating field and in a broader sense in the paper industry. The cause was the need to coat paper experimentally and the effect was the development of the pilot coater. Many other pilot coaters have been developed. A description of some of them will be given on the following pages.

UNIVERSITY OF MAINE'S PILOT COATERS

The University of Maine (3) has several pilot coating facilities. These include a reverse roll coater for

solvent coating, hot melt coating, waxing and laminating, a Warren laboratory air knife coater, and a pilot coater contributed by a supporter of that school. The latter is equipped with a roll train for high solids coating, and an air knife for low solids coating. It has etch rolls for gravure-type coating, and has recently been adapted with a trailing blade. It is said to coat a twelve inch web of paper at speeds up to 700 feet per minute.

WESTERN MICHIGAN UNIVERSITY PILOT COATER

Western Michigan University (4) has under construction a pilot size universal coater which will make possible five methods of coating: air knife coating, flexiblade coating, roll coating with high solids coating colors, and vertical and horizontal size press coating. An arched tunnel with medium velocity air will permit drying at speeds up to 2000 feet per minute. The machine will produce a coated sheet of 25 inch width after trimming.

CROWN ZELLERBACH'S PILOT COATERS

Crown Zellerbach Corporation (5), in its development laboratory, has also installed a pilot coater. Their machine is 50 feet long and will coat a 25 inch web at speeds varying from 30 to 300 feet per minute. It will do reverse-roll coating, airknife coating, gumming, saturating and laminating.

Also at Crown Zellerbach (6) in their central research department is another pilot coater. This is a 25 inch unit equipped with two flexible blade coaters. One is the conventional "puddle" type trailing blade, while the other permits the blade angle to be varied. The maximum operating speed of this unit is 700 feet per minute.

NATIONAL STARCH COMPANY PILOT COATER

A pilot plant of interest is that of the National Starch and Chemical Corporation Research Laboratory (7) at Plainfield, New Jersey. This plant is basically similar to full-size mill equipment, except for roll width. It is equipped to coat, dry and calender a web of paper. It will do the six major types of coating and sizing, air knife, trailing blade, roll, reverse roll, size press and modified size press.

The coater itself is 45 feet in length, 10½ feet high and has roll faces of two feet. It has 12 driven rolls with a maximum speed of 2000 feet per minute. The width of web that can be used varies from 20 to a maximum of 22 inches.

All the coating rolls are variable in ratios of 50 to 200 percent of drive input and may be operated in either direction. The trailing blade utilizes adjustable lucite dams with spring loaded faces. This blade has three con-

trols for automatic positioning, and complete movement in every direction. It incorporates a strong flexible spring steel blade.

The KMC (Kimberly Clark-Mead) process incorporates a 16 inch diameter brass backing roll (driven), a 16 inch diameter 85 P&J hardness bottom (application) roll, eight inch diameter chrome roll and a 12.75 inch diameter 60 P&J hardness gate roll. For the air knife process, air is supplied by a ten hp. centrifugal blower. This unit has a standard coating trough, coating applicator roll and breast roll.

A 16 inch diameter brass top roll and a 30 P&J hardness rubber bottom rolls, both driven, are utilized in the size press process.

The coater is powered by a 40 hp. motor generator set. It has a central drive shaft along the full length of the machine. Belts are used to transmit power from this line to right angle meter gear boxes. The gear units are coupled to positive infinitely variable (PIV) speed drive units (four to one ratio of variation).

Chain drives on the output shafts of the PIV units drive the rolls in the coater. In each case, a reversing transmission is coupled to the PIV unit. Positive power transmission is available at all speeds regardless of the load.

KOPPER COMPANY PILOT COATER

The Kopper pilot coater (8) is another of interest. This roll coater is equipped with two 14 inch diameter gate or feed rolls and an applicator and back up roll each 20 inches in diameter. All four rolls have 24 inch faces and are covered with 50 durometer rubber. The two gate rolls may be adjusted to operate between one third and three times machine speed. The application roll may be varied from machine speed through a varisheave to approximately plus or minus five percent. Coating may be applied up to 25 pounds per ream per side on a 20 inch web, at speeds up to 1500 feet per minute. Drying is done in a conveyer-equipped hot air tunnel.

BLACK-CLAWSON PILOT COATERS

This company (9) will soon have two pilot coating installations. The one in use at the present is in its solvent coating laboratory. This unit can test run solvent type coating by gravure, dip, squeeze, reverse roll and kiss coating processes. It can unwind 30 inch diameter rolls of paper, and features a 22 inch roll face universal coater with air doctor and a 50 foot convection dryer.

A new pilot plant under construction, will incorporate modern features of pigment coating and drying.

WALDRON PILOT COATER

Another extremely versatile pilot coater is the one

installed at the Waldron Research Facilities (10). This pilot plant will coat a 20 inch web of paper at speeds from five to 2000 feet per minute. The coater base is designed to mount a variety of coating heads including air knife, reverse roll, impregnating, knife, gravure and offset gravure, reverse smoothing roll, one and two side kiss coating and laminating attachments. By use of the proper heads, commerical processes can be duplicated, or by installation of specially built units, entirely new methods of web coating can be studied.

KOHLER PILOT COATER

At the 1959 Coating Conference, J. R. Gunning (11) presented a paper on the Kohler Coater. This 15 inch wide pilot machine was in operation at the Provincial Paper Company in Georgetown, Ontario. In the Kohler Coater, the coating is applied to the under side of a web of paper, being smoothed and metered by a blade of preselected thickness, which forms one of the boundaries of the pond from which the coating is picked up. The sheet is held to the blade by an air blast acting on top of the paper.

DIXON LABORATORY PILOT COATER

The Dixon Laboratory Coater (12), developed in Great Britain, will coat a continuous web of paper in a

variety of coating processes. It is equipped for single or double-sided coating controlled by pressure roller, for single-sided coating controlled by wire equalizer rods or scraper bars, and for impregnating under the control of pressure rollers or round scraper bars. The coating heads are adaptable for roller coating, brush coating and for impregnating or spreading. The coating speeds may vary from five to 160 inches per minute with the width of the web being twelve inches. Drying is done in a hot air tunnel or by the use of electric heaters. Rollers and coating trays may be electrically heated and thermostatically controlled.

The advantages of pilot coaters have been outlined at the beginning of this literature survey. However, since pilot coaters require a considerable quantity of coating materials, not to speak of cost of operation and investment, coating methods are needed which permit use of relatively small quantities of coating materials. Such coating methods are useful in preliminary screening of new materials and formulae.

BENCH TYPE LABORATORY COATING EQUIPMENT

Sheet coating is the earliest coating process known. Back in the 1830's all coated paper for commerical or for experimental purposes alike was coated by hand. The sheet

was laid on a table, and the coating was brushed on (13,14), often by a special badger hair brush (1). In modern laboratory coating, the brush-out method can still be found in rare instances, but most laboratories have shifted to other procedures which have significant advantages over brush-outs. To mention a few laboratory devices, wire wound doctor rods, the Martinson blade coater, the Bench type trailing blade coater, and the Bird film applicators are used quite regularly.

WIRE WOUND DOCTOR RODS

The most widely used applicators for coating colors and the least publicized devices are glass, metal or wire wound rods. These doctor rods are usually stainless steel covered with different fine gage wires to apply various coating weights. The amount of coating applied is determined by the gage of the wire. In the literature, hardly anything could be found pertaining to this particular procedure and there-fore it could be assumed, with a deal of certainty, that most of the information on this technique has been passed on by word of mouth.

Several references in the literature mentioned the use of wire wound doctor rods, but did not give any details of the procedure. Casey (1) and Mosher (15) in their books, and Tompkins (16) and Errat (17) in their publications

referred to the technique. Tompkins did say that the stock was laid on plate glass and coated with a number five Meyer bar or wore-wound rod.

MARTINSON COATER

Another small size sheet coater, widely used in the forties, is the Martinson laboratory coater. This is a precision instrument for spreading a liquid film on paper or flexible base. It is 36 inches long, twelve inches wide and 15 inches high.

Landes (18) and Upright (19) in their articles both reported that the operation of this coater proceeds as follows: The raw stock is cut with the grain across the machine to minimize wrinkles, into 9.5 by 12 inch sheets and placed felt side up on the coater. The machine direction should be parallel to the coater doctor to prevent uneven coating deposition due to curling of the stock. The coating color is then poured on the edge of the sheet nearest to the doctor blade and the sheet is immediately pulled under the blade with a smooth stroke. The speed to be used is acquired through practice and should be moderate but steady.

Various weights of coating color can be applied by changing the setting of the blade by means of a micrometer gage which controls the distance between the paper and the blade. The uniformity of the spread and the coat weight will depend mainly upon the coating color viscosity and

the speed of travel of the table. After several runs, the doctor blade setting can be adjusted to apply a previously determined coat weight.

Roderick (20) and Stilbert (21) referred to experimental coating by means of a Martinson Coater. Casey (1) also stated that this machine could be used to coat paper in the laboratory.

BIRD FILM APPLICATORS

Another instrument, widely used to coat paper in the laboratory, is the Bird film applicators. Although Casey (1) and Mosher (15) state that one can coat paper experimentally using the Bird film applicator, no additional information was found during this literature survey.

BENCH TYPE TRAILING BLADE COATER

The Bench Type trailing blade coater is a rather recent development, thus no reference was found in the literature yet. From blueprints and the operating instructions received from the manufacturer (22), the following information was obtained. The Bench Type trailing blade coater was developed by Time Inc. as a tool for applying a uniform layer of coating to a 6.5 by 11 inch sheet of paper or paperboard. The coater is approximately 13 inches high, 14 inches wide and weighs about 50 pounds.

The main component of this coater is a back-up cylin-

der, seven inches in diameter, 10.75 inches wide, with a .0625 inch rubber covering. The coating blade is 8.0 inches long by 2.5 inches wide and is made of 0.012 inch blue spring steel with a honed coating edge. The coating blade is held evenly against the back-up cylinder by air pressure through a rubber tube. The air pressure can be varied between zero and 30 psig by a pressure reducing valve and a gage attached to a panel on the back of the coater. Adjustment of the coat weights can then be made by varying the pressure on the coating blade.

The Bench type trailing blade coater operates as follows: The back-up cylinder is wrapped with a back-up paper (10 by 23 in.), this being taped in place with scotch tape. The lead end of the sample sheet (7 by 12 in.) is then taped to the back-up sheet. The narrow size of the sample sheet was selected because, if the sample sheet was wider, the beads of coating from the blade would end up on the sample sheet which is undesirable. The coating color is applied to the leading edge of the sample sheet, by use of a spatula. The coating color is spread evenly over the sample as the back-up cylinder is slowly rotated past the blade by means of a hand crank. If the coating solution is of low viscosity and will run readily, the cylinder should be turned to its starting position and the coating should be poured in the nip between the blade and the paper.

TRAILING KNIFE COATER

Another bench type laboratory device was discussed by Jones and Quackenbush (23). This machine was built to study the trailing knife coating process. In this process the coating was applied by a blade pressing against a sheet which was affixed to the periphery of a narrow rubber covered roll. The roll was powered by a spring drive which accelerated the cylinder to approximatley 850 feet per minute and back to zero in slightly less than one revolution. Higher speeds were obtainable if needed. The results obtained with this machine could be correlated very well with commerical operations. It was said to be a useful tool for coating formulation work, and investigation of the mechanical variables found in the trailing blade process.

WALLACE ROLL COATER

Another sheet coater built in 1957 by the L. R. Wallace and Company (24) is a roll coater. It features a pick up roll and transfer roll. This device has an adjustable bottom roll, which is said to eliminate the necessity for disturbing the coating roll adjustment for a variety of material thicknesses. This coater is available with steel or rubber rolls for ink, lacquers, enamels and a wide variety of coating materials. Transfer and pick-up rolls measure 2.5 inches in diameter and spreader and pressure rolls measure four inches.

Because of the wide spread interest in the coating field and the limited quantity of literature available on laboratory coating procedures, this survey was written. It was intended to provide a base from which a comparison of several bench type coating methods could be made experimentally in the laboratories of the Department of Paper Technology at Western Michigan University.

EXPERIMENTAL DESIGN

The objective of the experimental work is to compare the performance of four bench type laboratory coating devices. These are the Martinson Coater, the Bench Type Trailing Blade Coater, Bird Film Applicator, and Wire Wound Doctor Rods.

The performance of these devices is to be evaluated at different levels of coat weight. The weights will be varied, if possible, from 3.0 to 6.0 to 12.0 to 24.0 pounds per ream (25x38-500).

All coating work is to be carried out with a coating color which possesses uniform composition of its solids content. This is to consist of 100 parts of premium grade coating clay, 18 parts of casein, 0.2 parts of tetrasodium pyrophosphate, and other additives if needed.

It is planned to keep the solids content of the coating color uniform as far as possible. However, in some cases, particularly in the case of the Bench Type Trailing Blade Coater, variation in solids content may be necessary.

The body stock to be coated will be black paper or paperboard suitable for this project. Black paper to be used because the pattern formed by each instrument will show up more distinctly on a dark background.

The coated sheets will be air dried. Evaluation of the coated sheets will be carried out from the viewpoint of pattern formation. It is impossible, with present coating machinery (laboratory or otherwise), to produce a coated sheet that does not show a typical pattern formation. Pattern is important and undesirable from the printing standpoint as it reflects the non-uniformity of the sheet. Smoothness, ink receptivity, printing pressure and many other printing properties are directly affected by pattern.

There are two significant ways of controlling pattern formation:

1. Vary the rheology of the coating.
2. Change the manner in which the coating is applied.

For this thesis work, the rheology of the coating slip is to be kept constant and only the manner in which the coating is applied will change.

The evaluation of the coated sheets and thus the performance of the four devices is to be carried out by visual inspection in daylight and arbitrary rating will be assigned.

Plans are made to keep a photographic record of the most characterestic patterns.

As smoothness is closely related to pattern a record of the smoothness of sheets producted by the four devices will

be kept.

The effect of supercalendering on the sheets will be duely noted and recorded.

EXPERIMENTAL PROCEDURES, TECHNIQUES, AND MATERIALS

COMPOUNDING COATING COLOR

Preparation of Clay Slurry A master batch of 76.8 per cent clay slurry was prepared for compounding coating color. A domestic, pedispersed, spray-dried clay with particle size 80% less than two microns was used. A 70% percent clay slurry had been planned, but it was found that higher percent solids could be obtained. The clay slip was dispersed in a Day Mixer at 76.8 percent solids for twenty minutes after dilatency had been reached. At the beginning of shearing, a dispersing agent (0.2 percent tetrasodium pyrophosphate based on weight of clay) was added in form of a five percent solution. The pH of the clay slurry obtained was found to be seven (Beckman pH meter) which was too low for good storage. Sodium hydroxide (0.05 percent based on weight of clay) was added to raise the pH to the eight to nine range. The formulation of the clay slurry is shown in TABLE I.

Preparation of Casein Solution A 20 percent casein (30 mesh Argentine) solution was prepared with the aid of four percent sodium hydroxide based on dry solids.

TABLE I FORMULATION OF CLAY SLURRY

PARTS	DRY WEIGHT (grams)	WET WEIGHT (grams)
Clay	3300	
Dispersing Agent	6.6	132
Water		868
NaOH	1.65	33
Total Solid Content, percent	76.8	

TABLE II FORMULATION OF CASEIN SOLUTION

PARTS	DRY WEIGHT (grams)	WET WEIGHT (grams)
Casein	200	
Sodium Hydroxide	8	160
Preservative	6.6	165
Hexamethylenetetramine	6.6	165
Water		289
Total Solid Content, percent	20	

Water and casein were weighed out separately and added simultaneously to a double boiler with good stirring. The mixture was mixed until smooth and heated to the 130°F (52.2° C). Sodium hydroxide was added along with 3.3-4 percent hexamethylenetertramine and 3.3-4 percent preservative (sodium pentachlorophencol). The receipe for the 20 percent casein solution is shown in TABLE II.

Preparation of Coating Color The coating color contained eighteen parts casein per 100 parts clay. The required amounts of clay slurry and casein solution was weighed out separtely. The casein solution was added slowly to the clay slurry with good mixing (Lightnin laboratory mixer). After thorough blending the total solids content of the coating color was adjusted to 40 percent and the pH to the eight to nine range for good storage. The coating color was centrifuged each time before use for ten minutes at 1000 revolutions per minute on an International Centrifuge.

Viscosity of Coating Color A Brookfield viscosity reading was taken each time before use. A No. 5 spindle

use. A No. 5 spindle was used in each case at 10, 20, 50, and 100 revolutions per minute. All readings were taken on the 100 scale.

It was found that the viscosity of the coating color was lower each week, without any apparent spoilage. Spoilage would have been detected by its characteristic ordor. No reasonable explanation could be arrived at for this decrease until it was discovered a "loss in adhesive strength without spoilage taking place is attributed to the presence of enzymes which are destroyed conventionally by heat. Generally a temperature of 160°F is required to destroy the enzymes". (25) The casein had been heated to a temperature of only 130°F for this thesis work.

DESCRIPTION AND HANDLING OF BASE STOCK

The base stock consisted of black paper (45 pound basis weight for a 25x38-500 ream) obtained from the Eastman Kodak Company. The paper was not a precoated or sized coating base stock and it was realized that subsequent tests would be influenced by this factor.

The paper was cut into the following sizes on a lab-

oratory trimmer for each instrument

Wire Wound Rods	12 by 18 inches
Bird Film Applicators	8 by 12 inches
Bench Trailing Blade	7 by 12 inches
Martinson Coater	9.5 by 12 inches

COATING PROCEDURE

Wire Wound Doctor Rods The base sheet, felt side, was laid on a pad of back up paper approximately one half inch in thickness. By means of clamps secured to the laboratory desk, both the base sheet and back up papers are fastened so no movement of these sheets will be encountered in the coating operation. A bead of coating was applied across the top of the base sheet and this is drawn down with the wire wound rod.

The procedure outlined above was used in obtaining the number of the doctor rods used to apply the various coat weights. Precoated white 45 pound basis weight paper (25x38-500 ream) was used for this work.

It was found during this work that these coatings were influenced by the thickness and smoothness of the pad of back up paper, the pressure on the doctor rod during coating and the speed with which this instrument was

drawn down the sheet during the coating operation. These are not proven facts but observations made by this experimenter as the work involved laid outside the area encompassed by this thesis.

Bird Film Applicators The procedure used to apply coatings with these instruments was the same as that outlined above for wire wound doctor rods.

Bench Trailing Blade The procedure for applying coatings with this device is the same as that found in the literature survey on page 15.

Martinson Coater The coating procedure used with is instrument is found on page 14 of the literature survey.

HANDLING OF THE COATED SHEETS

Trimming of the Coated Sheets The coated sheets were trimmed to a specified size by running a razor blade around a piece of stainless steel of that size. The sheets were trimmed to the following sizes:

Wire Wound Doctor Rods	9.5 by 12 inches
Bird Film Applicators	5 by 9 inches
Bench Trailing Blade	6 by 9 inches
Martinson Coater	6 by 9 inches

Basis Weight and Coat Weight   Basis weight of both the black and white paper was obtained by weighing a sheet of known area and calculating the weight back to a 25x 38 - 500 ream. Coat weight was determined by the difference method and calculated back to the same ream size.

Supercalendering of the Coated Sheets   After testing, the coated sheets were supercalendered on a three roll laboratory supercalender using four nips at 40 pounds gage pressure. The sheets had been previously conditioned at 73°F plus or minus two degrees and at 50 plus or minus two percent relative humidity for at least two hours.

EVALUATION OF THE COATED SHEETS

Visual inspection   The coated sheets were visually inspected in daylight to determine the amount and extent of pattern, the evenness of coat weight distribution and any other significant factors.

After supercalendering, the sheets were analyzed to determine the effect of supercalendering on the above characteristics.

Smoothness of the Coated Sheets Bekk smoothness reading were taken on both the unsupercalendered and supercalendered sheets. Tappi Standard procedure was followed, except that only four smoothness readings were taken on each

sheet instead of ten as the Standards recommend. This modification was made in the interest of conserving time.

PHOTOMICROGRAPHS

Photomicrographs were made of the characteristic patterns obtained from each instrument before and after supercalendering. A polaroid camera was used which was mounted in a Cenco-Polaroid Micrography camera support. The camera was focused through a microscope whose magnification was set at 30. Total magnification used was 20. Samples to be photographed were fastened on a microscope slide using double face scotch tape. The slide was placed on the microscope table and focused on a piece of frosted glass which was in the position the film would be in the camera. The microscope setting was noted so it could be reproduced after film had been placed in the camera.

A Baush and Lamb Light source was used and the angle of incidence was 13°, measured with a protractor.

DISCUSSION AND PRESENTATION OF RESULTS

VISUAL INSPECTION A visual inspection of the coated sheets shows one point clearly. A different pattern is obtained from each instrument. Doctor Rods gave a streaky pattern which was most noticeable at low and medium coat weights. After supercalendering the streaking was less pronounced but still very noticeable.

The Bird Film Applicators produced the least pattern of these four instruments. Their pattern consisted of a very short streaking effect about one fourth inch in length. After supercalendering this pattern became more pronounced.

A mottled pattern was obtained from the Bench Trailing Blade Coater. This was less pronounced after supercalendering but still very apparent.

The pattern obtained from the Martinson Coater was widely varied and very noticeable. In practically all cases, a great deal of streaking was evident along with an uneven disposition of coat weight.

If arbitrary rating was assigned to these four instruments on the basis of least pattern, the Bird Film Applicators would be first, followed by Doctor Rods, Bench Trailing Blade and Martinson Coater.

Samples of the pattern produced by these four instruments are shown in Figures 1-13.

SAMPLES OF PATTERN

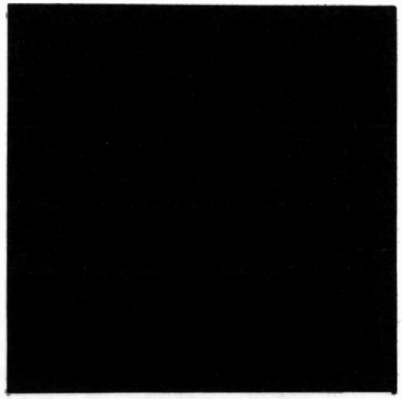


Fig. 1
BLACK PAPER
Uncalendered
Basis wt. 45#/ream

Fig. 2
DOCTOR ROD
Uncalendered
Coat wt. 3.9#/ream

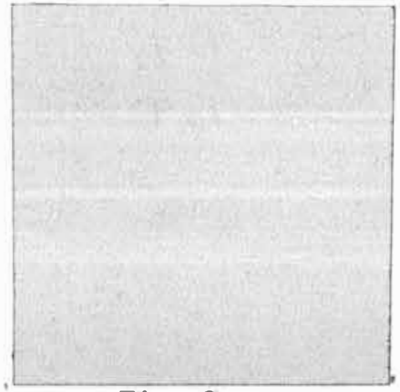


Fig. 3
DOCTOR ROD
Uncalendered
Coat wt. 13.4#/ream

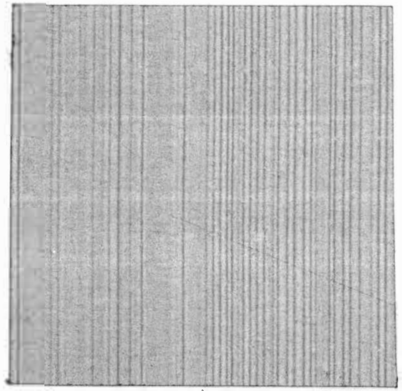


Fig. 4
DOCTOR ROD
Uncalendered
Coat wt. 7.4#/ream

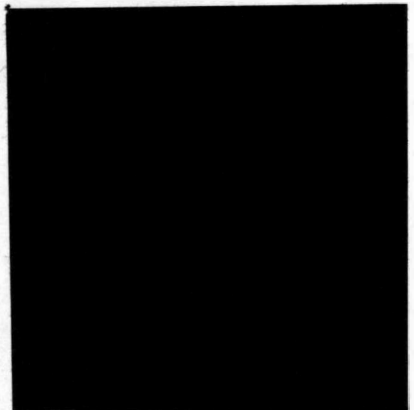


Fig. 5
BLACK PAPER
Calendered
Basis wt. 45#/ream

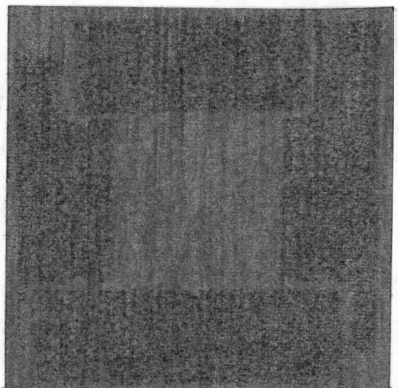


Fig. 6
DOCTOR ROD
Calendered
Coat wt. 3.0#/ream

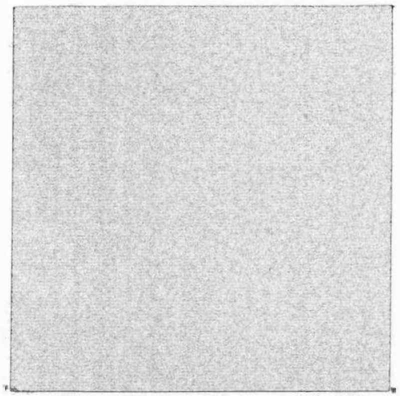


Fig. 7
DOCTOR ROD
Calendered
Coat wt. 23.3#/ream

SAMPLE OF PATTERN

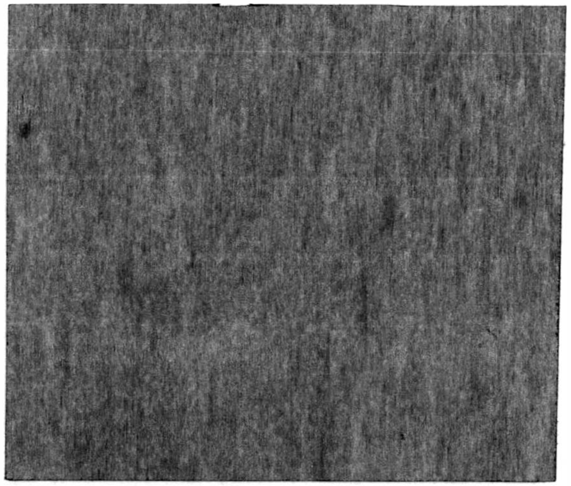


Fig. 8
BIRD FILM
Uncalendered
Coat wt. 2.41#/ream

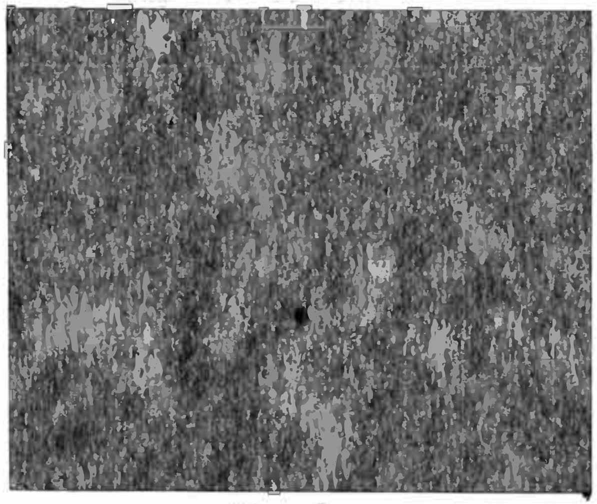


Fig. 9
BENCH TRAILING BLADE
Uncalendered
Coat wt. 3.4#/ream

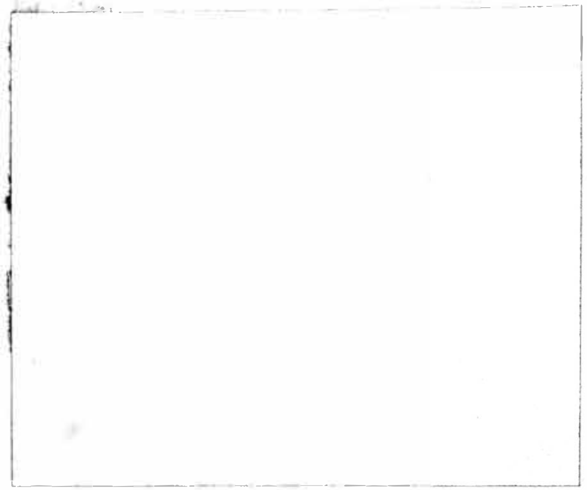


Fig. 10
MARTINSON
Uncalendered
Coat wt. 19.9#/ream

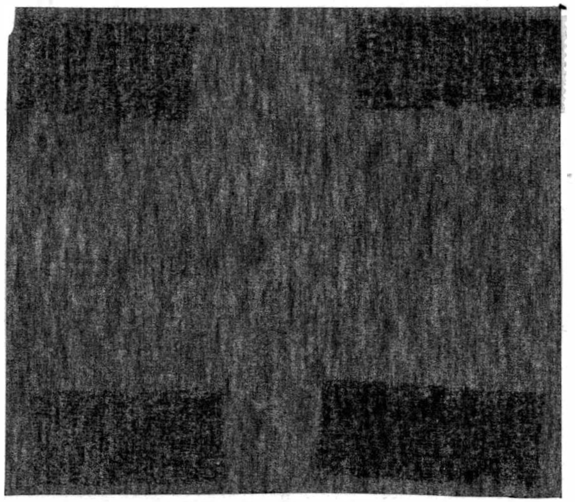


Fig. 11
BIRD FILM
Calendered
Coat wt. 2.41#/ream

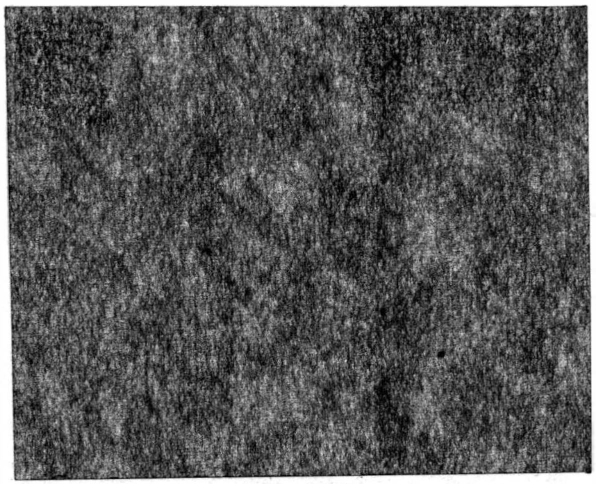


Fig. 12
BENCH TRAILING BLADE
Calendered
Coat wt. 3.40#/ream

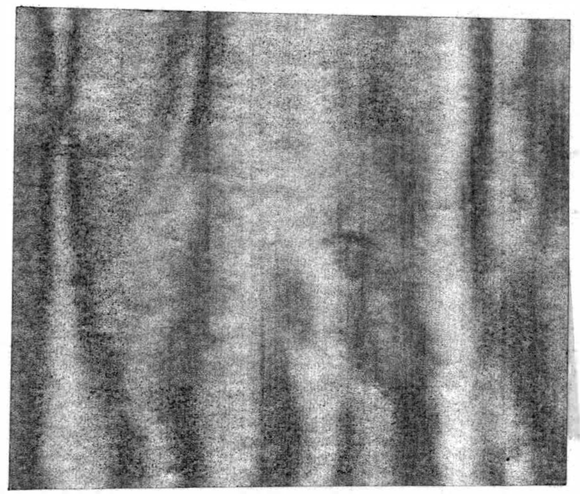


Fig. 13
MARTINSON
Calendered
Coat wt. 8.2#/ream

COAT WEIGHT AND REPRODUCIBILITY

Coat weight values obtained using the laboratory coaters are shown in TABLES IV-VI. These figures show that the minumun and maximun coat weights obtainable from each instrument are as follows:

Wire Wound Doctor Rods	3 to 23 pounds per ream (25x38-500)
Bird Film Applicators	1.7 to 5 pounds per ream
Bench Trailing Blade	3.4 to 6.7 pounds per ream
Martinson Coater	8.2 to 50 pounds per ream

From these values it can easily be seen that only low coat weights can be applied with Bird Film Applicators and Bench Trailing Blade equipment while low, medium and fairly high coat weights can be produced by Doctor Rods. The Martinson Coater is good for medium and very high coat weights.

The reproducibility for these four instruments was generally very poor. TABLE VII shows the average deviation of coat weight along with average deviation as a percent of total coat weight. It can be seen that the Bird Film Applicators and the Bench Trailing Blade Coater have smaller average deviations, but larger percent deviations when compared to total coat weight applied.

The interesting point of this table is the average deviation in coat weight obtained with 12A, 12B and 12C doctor rods. These are the same number rods having the same mesh wire and consequently they should give the same coat weight. These three rods gave coat weights of 9.75, 10.05 and

TABLE III

VALUES FOR COAT WEIGHT AND SMOOTHNESS

WIRE WOUND DOCTOR RODS

ROD NO.	RUN	COAT WEIGHT (POUNDS/REAM)	BEKK SMOOTHNESS (SECONDS) BEFORE CALENDERING	AFTER CALENDERING
3	1	3.4	15.3	629
	2	3.4	17.0	679
	3	3.5	16.7	668
	4	3.40	15.3	629
		3.32 Average		
6	1	6.5	25.4	921
	2	4.1	17.25	764.5
	3	5.0	23.2	848
	4	7.10	16.0	849
		5.67 Average		
12A	1	11.5	32.22	952
	2	7.4	15.72	---
	3	10.0	25.35	936
	4	10.1	32.0	830
		9.75 Average		
12B	1	9.70	23.6	910
	2	8.90	23.15	965
	3	12.5	34.8	981
		10.05 Average		
12C	1	12.40	33.5	979
	2	10.1	25.5	870
	3	12.3	34.1	986
	4	10.0	27.2	888
		11.20 Average		
30	1	19.1	33.95	1021
	2	19.9	31.1	1021
	3	22.2	41.75	1015
	4	20.3	32.75	1021
	5	23.3	27.75	1016
		20.94 Average		

TABLE IV

VALUES FOR COAT WEIGHT AND SMOOTHNESS

BENCH TRAILING BLADE COATER

	COAT WEIGHT (POUNDS/REAM)	BEKK SMOOTHNESS (SECONDS) BEFORE CALENDERING	AFTER CALENDERING
PRESSURE 5#/SQ. IN.			
RUN 1	6.69	22.4	741.5
2	6.30	35.7	698.5
3	3.98	19.65	658.0
4	4.38	26.3	708.0
	5.62 Average		
PRESSURE 10#/SQ. IN.			
RUN 1	6.11	24.9	675
2	5.72	22.8	656
3	6.30	25.0	662.5
4	3.93	18.2	656.5
	5.57 Average		
PRESSURE 15#/SQ. IN.			
RUN 1	3.78	17.6	617.5
2	4.75	18.2	661.5
3	3.40	16.85	624.5
4	3.98	18.9	630
	3.98 Average		
PRESSURE 20#/SQ. IN.			
RUN 1	5.33	23.6	639.0
2	3.40	16.0	597.5
3	4.95	22.75	626
4	3.40	18.3	597.5
	4.27 Average		

TABLE V

VALUES FOR COAT WEIGHT AND SMOOTHNESS

BIRD FILM APPLICATORS

SIZE	COAT WEIGHT (POUNDS/REAM)	BEKK SMOOTHNESS (SECONDS) BEFORE CALENDERING	AFTER CALENDERING
Size .005			
Run 1	2.41	17.7	573.5 Sec.
2	4.50	26.1	562.2
3	3.57	20.9	606.2
4	2.64	15.8	593.2
5	4.96	26.5	628
	3.61 Average		
Size .001			
Run 1	2.88	17.25	638.7
2	4.50	24.35	651.5
3	5.65	28.3	627.2
4	4.96	29.75	652.5
5	5.07	29.8	716.0
6	5.65	30.3	715
	4.78 Average		
Size .0015			
Run 1	4.50	27.5	----
2	2.41	21.2	----
3	1.72	17.1	----
4	4.26	24.8	738
5	2.88	22.5	684
	3.15 Average		
Size .003			
Run 1	3.11	25.6	744.0
2	2.88	19.4	678.0
3	4.72	28.7	715
4	3.57	24.7	688.5
5	2.18	17.2	625
	3.29 Average		

TABLE VI

VALUES FOR COAT WEIGHT AND SMOOTHNESS

MARTINSON COATER

COAT WEIGHT (POUNDS/REAM)	BEKK SMOOTHNESS (SECONDS) BEFORE CALENDERING	AFTER CALENDERING
8.8	24.15	819
8.9	28.3	845
9.6	24.3	876
13.2	33.25	1010
17.8	30.75	991
22.76	31.35	929
23.7	37.9	879

TABLE VII

AVERAGE DEVIATION AND DEVIATION AS PERCENT OF TOTAL COAT WEIGHT

APPLICATOR	COAT WEIGHT (POUNDS/REAM)	AVE. DEVIATION	% TOTAL COAT WT.
Doctor Rod 3	3.32	0.16	4.8
" 6	5.67	1.12	20.0
" 12 No. 1	9.75	1.17	12.1
" 12 No. 2	10.05	1.22	12.1
" 12 No. 3	11.20	1.15	10.4
" 30	20.94	1.40	6.7
Bird Film .0005	3.61	0.89	24.6
" .001	4.78	0.73	15.3
" .0015	3.15	0.98	31.1
" .003	3.29	0.68	20.6
Bench Trailing Blade			
Pressure 5#/ Sq. In.	5.26	1.16	22.0
" 10#/ Sq. In.	5.57	0.75	13.4
" 15#/ Sq. In.	3.98	0.39	9.8
" 20#/ Sq. In.	4.27	0.87	20.3

11.20 respectively which is rather poor corelation between rods of the same number, but their average deviation 1.17, 1.22 and 1.15 and their deviation as their percent of total coat weights, 12.1, 12.1 and 10.4 respectively all gave very good corelation. From this it would have to be concluded that for any technical coating work using wire wound doctor rods that only one rod should be used for any specific coat weight.

SMOOTHNESS OF THE COATING SHEETS

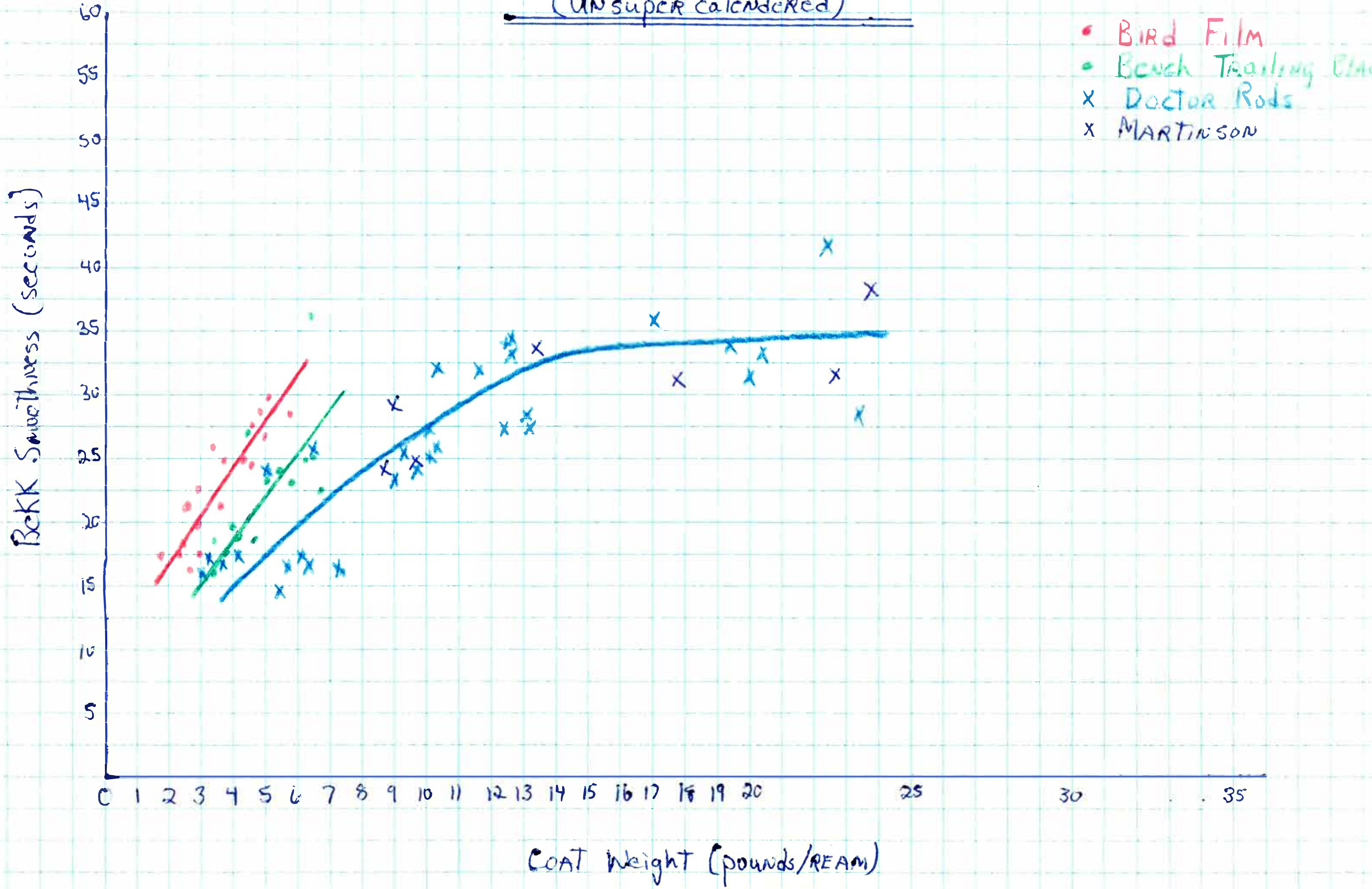
Graphs I and II show Bekk smoothness in seconds plotted against coat weight in pounds per ream. From Graph I it can be seen that before supercalendering, the Bird Film-coated sheets gave the highest smoothness values. Slightly lower, about five seconds, were the Bench Trailing Blade, Wire Wound Doctor Rods and Martinson Coater Values.

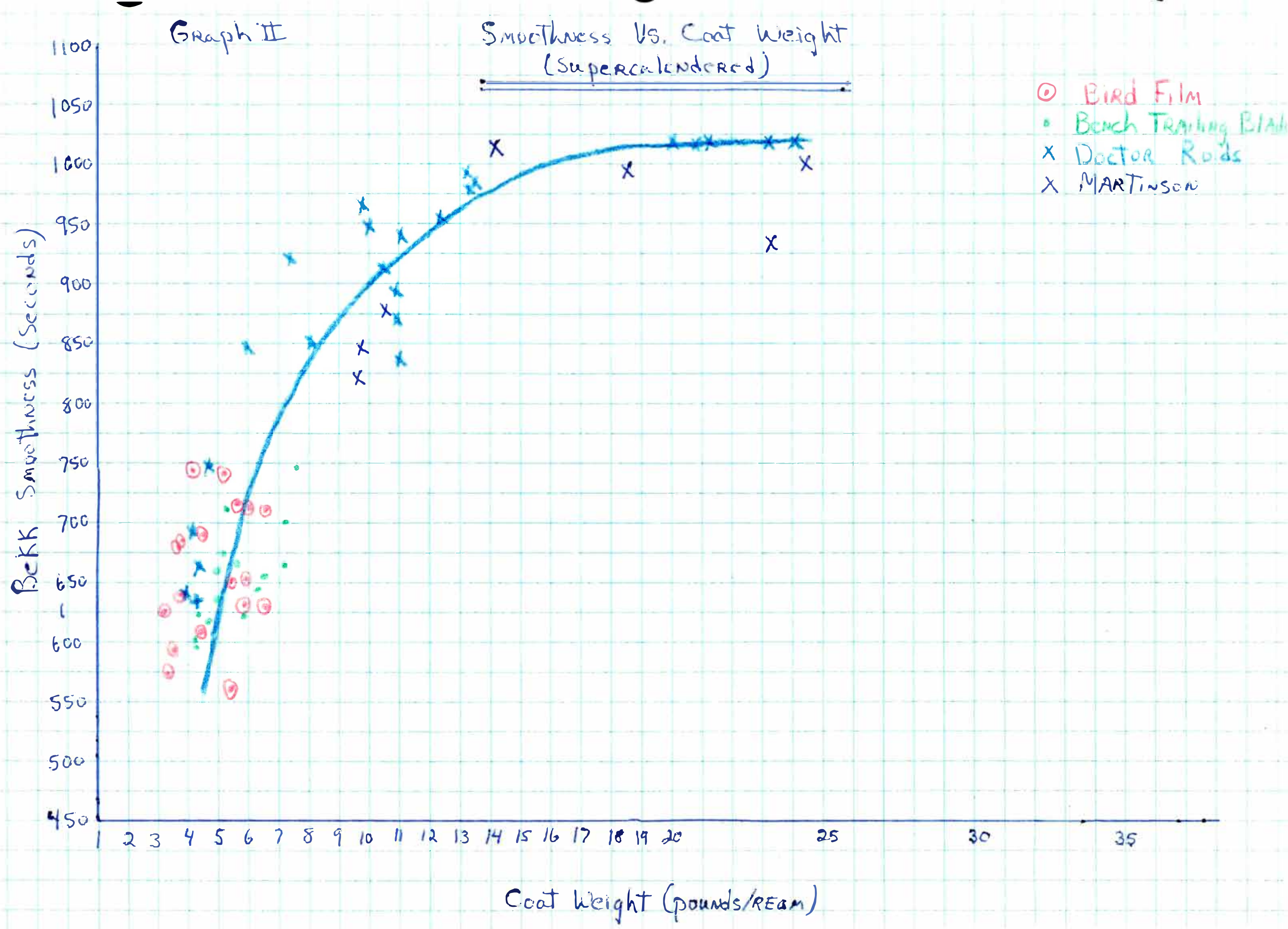
Graph II shows that after supercalendering, the points for all four instruments fall into the same general area. The Bird Film values, however, exhibited much more scattering after supercalendering than before.

For both the unsupercalendered and supercalendered sheets, the smoothness values for Doctor Rods increased until a coat weight of about fifteen pounds per ream was reached and then leveled off.

Graph I

Smoothness Vs. Coat Weight
(Unsupercalendered)





Graph II
Smoothness Vs. Coat Weight
(Supercalendered)
Bird Film
Bench Trailing Blad
Doctor Rods
Martinson
Bekk Smoothness (Seconds)
1100
1050
1000
950
900
850
800
750
700
650
600
550
500
450
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 25 30 35
Coat Weight (pounds/ream)

The smoothness values indicate that:

1. Before supercalendering a notable smoothness differences between these four instruments was evident which is to a large extent attributed to the variation in pattern formed by the application method.

2. After supercalendering the smoothness variation is less noticeable indicating that the surface of the sheets are smoothed by the supercalendering action. This conclusion is verified by the photomicrographs.

PHOTOMICROGRAPHS

An arbitrary evaluation of the photomicrographs of the supercalendered sheets suggests that the Bench Trailing Blade Coater has the roughest surface. The ridges and valleys in these coatings are readily distinguishable under the microscope. The Martinson Coater is next roughest followed by the Doctor Rods and the Bird Film Applicators.

It may be noticed in the photomicrographs that the Doctor Rods exhibited a pin hole-like phenomenon which seemed to decrease as higher coat weights were applied. No explanation is available for this effect, as the coating was centrifuged and little if any air was present in the coating slip.

After supercalendering, photomicrographs of the sheets surfaces all appeared about the same. This conclusion seemed to agree with the smoothness values obtained after supercalendering. The pin hole-like effects were still observed in the Doctor rod coating.

Samples of the photomicrographs taken are shown in Figures 14-21.

PHOTOMICROGRAPHS
SAMPLES OF PATTERN

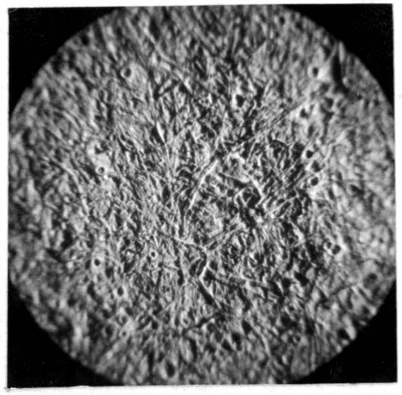


Fig. 14
DOCTOR ROD
Uncalendered
Coat wt. 3.0#/ream

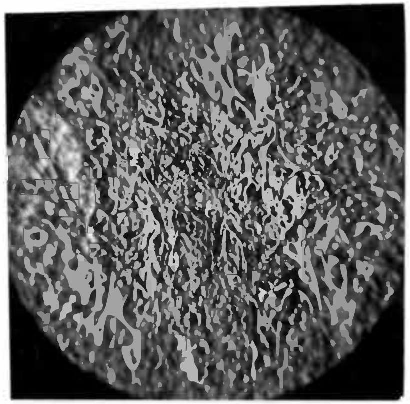


Fig. 15
BIRD FILM
Uncalendered
Coat wt. 2.41#/ream

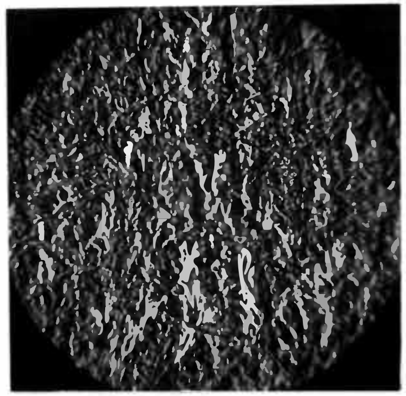


Fig 16
BENCH TRAILING BLADE
Uncalendered
Coat wt. 3.40#/ream

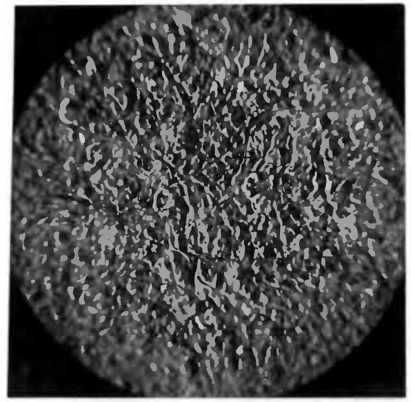


Fig. 17
MARTINSON
Uncalendered
Coat wt. 8.2#/ream

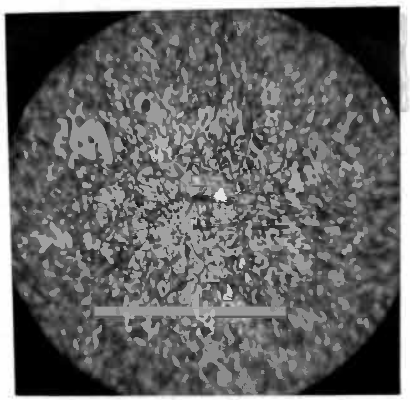


Fig. 18
DOCTOR ROD
Calendered
Coat wt. 3.0#/ream

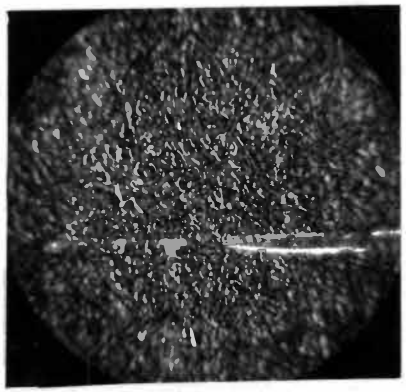


Fig. 19
BIRD FILM
Calendered
Coat wt. 2.41#/ream

Fig. 20
BENCH TRAILING BLADE
Calendered
Coat wt. 3.40#/ream

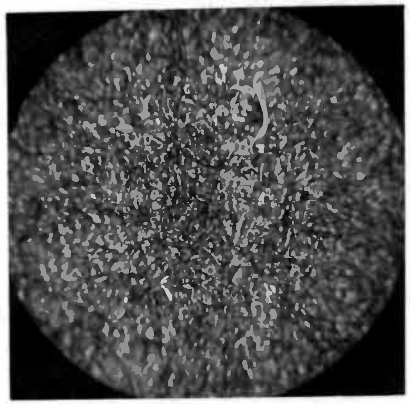


Fig.21
MARTINSON
Calendered
Coat wt. 8.2#/ream

CONCLUSIONS

1. A distinctly different coating pattern is obtained from each of the four instruments.

2. Bird Films and the Bench Trailing Blade Coater will apply low coat weights while Doctor Rods produce low, medium and high weights. The Martinson Coater can be used for medium and very high coat weights.

3. The reproducability of these instruments is very poor. Large variations were found between runs with the same setting and between runs of different instruments with the same setting.

4. In technical coating work using Doctor Rods, only one rod should be used for any specific coat weight.

5. Before supercalendering a noticeable smoothness difference is indicated between these instruments which to a large extent is attributed to the variations in pattern formed by the application method.

6. After supercalendering, the smoothness variation is less noticeable, indicating that the surface of these sheets are smoothed by the calendering action. This is verified by the photomicrographs and the smoothness values of the supercalendered sheets.

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