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Synthetic Polymers in Coating Colors: The Adhesive Values of Lattices and Their Effects on Properties of Laboratory Coated Papers

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SYNTHETIC POLYMERS IN COATING COLORS

THE ADHESIVE VALUES OF LATICES AND THEIR EFFECTS ON PROPERTIES OF LABORATORY COATED PAPERS

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Properties of Laboratory Coated Papers

SUMMARY

Five synthetic latices have been evaluated as to their adhesive values and influence on optical properties of the coated papers.

The five synthetic polymers were acrylates, acrylonitrile-butadiene, polyethylene, polystyrene-butadiene, and vinyl acetate.

The latices were used to substitute, on a pound per pound basis, 25, 50 and 75 percent of the casein used as binder in a standard coating color consisting of 100 parts of coating clay and 16 parts of casein.

Higher adhesive values than that of straight casein were established by acrylates and two butadiene copolymers. Vinyl acetate and polyethylene possessed lower adhesive values than straight casein color.

Outstanding optical characteristics, gloss, opacity, and brightness, were obtained by use of vinyl acetate whereas the other synthetics were either equal or inferior to casein in their performance.

Synthetic Polymers in Coating Colors

The Adhesive Values of Latices and Their Effects on

Properties of Laboratory Coated Papers

PART I. LITERATURE SURVEY

INTRODUCTION

One of the rapid growing branches of the paper-coating industry is concerned with latices which are water dispersions of synthetic and natural high-polymeric film formers. The term emulsion system is used in coating to denote a dispersion which is prepared with water, as part of the formulation. A latex is any colloidal dispersion of an elastomer or polymer of microscopic particles in water. (1)

A polymer is a substance consisting of molecules which are, at least approximately, multiples of low-molucular-weight units. The low-molecular-weight unit is monomer. All adhesives, natural and synthetic, are polymers. In nature, the polymerization takes places in the tissue of the plant or animal; the synthetic polymers are artificially-made high-molecular-weight compounds.

A coating color is a mixture mainly composed of pigment in a water-dispersion of adhesive which is used to bind the pigment particles to

each other and to the paper surface.

Since the adhesives used in coating of paper will vary in their degree of efficiency, the term "adhesive value" is introduced and defined as follows: The adhesive value is a quantity which shows how much stronger or weaker an adhesive is than a good grade of commercial lactic casein which serves as empirical standard. Therefore, if an adhesive value is below than one, it denotes that this adhesive value in adhesion properties **weaker** than casein; and if an adhesive value is above one, it denotes that this adhesive is stronger in adhesion characteristics than casein.

A BRIEF REVIEW OF ADHESION IN COATING COLOR

The function of an adhesive in coating color has been stated in the previous section. The adhesive exerts a profound influence on the properties of the coating mixture and the characteristics of the final coated paper. (2) The adhesive effect of high-molecular substance is traced to the nonadsorbed part of the chain molecules which protrude from the adsorption layer and thereby transfer forces into the adhesive layer when subjected to tensile or shear stresses. (3) Douglas(4) states that adhesion of high polymers to cellulose is governed by three factors:

(1) The adhesion of polymers to cellulose is a function of tack

temperature and dielectric constants of polymers and of dipole moments of polymer polar substitutes.

(2) The adhesion is a specific function of the nature of the polar groups within the polymer and on the modified cellulose.

(3) The interdependence of heat of adsorption and cohesive energy on the temperature dependence of adhesion have close relationship.(4)

The required properties of a coating adhesive are:

(1) An adhesive should have high pigment bonding strength and good color.

(2) It should not obscure the properties of the pigment and produce with the pigment a surface that is highly receptive to printing ink.

(3) It must have the correct viscosity for the solid content at which the coating mixture is to be used and produce a coating mixture with a degree of colloidal stability.

(4) It should have strong filming properties to prevent excessive penetration of the coating mixture into the raw stock at the time of application and have enough plasticity so that the coating will not powder or dust during calendering. (2)

The pigment bonding strength is determined by the cohesive strength between the adhesive moleculas and by the adhesive bond formed between the adhesive, the pigment, and the raw stock. (2)

PIGMENT DISPERSION PHENOMENA

When a small amount of pigment is added to a latex polymer the resulting film will be composed of pigment aggregates which are completely separated from each other by the polymer. As the pigment aggregates decrease until insufficient polymer is present to maintain complete separation of pigment aggregates. Figure 1 shows an idealized concept of latex bonding. (5)

The point at which complete separation between pigment aggregates is maintained with the least amount of polymer is the "critical pigment volume concentration". This point is the limiting factor for those uses in which a continuous polymer film is desired. The determination of the critical pigment volume concentration for various pigments is an important property to the formulator.(5)

LATICES FOR PIGMENT COATING

There is an appreciate number of latices commercially available for pigmented coating of paper. The classification of some latices by composition is listed as Table I.

GENERAL PROPERTIES OF SYNTHETIC LATICES

Particle Size Particle size and its influence on latex stability are the most important subjects to be considered in compounding and using any synthetic latex. On the average, the particle size of synthetic polymer latices is much small than that of natural Hevea latex. There is an enormous increase in hydrophobic surface as particle diameter of a rubber or plastic latex is reduced. Stability of the heterogeneous system requires that some minimum quantity of protective agent be associated with this surface. The affinity between the surface of the polymer particle and the surface active agent is very great.

A calculation of hypothetical systems at several uniform particle diameters is listed in Table II.

Surface Active Emulsifier In most synthetic latices, surface active materials are used in the emulsion polymerization or dispersing process and prevent agglomeration of the particles by maintaining a hydrophobic surface that is usually electrically charged by ionization. Stability is usually varied by charging the amount of surface active material in a given latex. Stabilizer requirem ent for a specific application and latex depend primarily on particle

size and manner of use, but are also effected by type of polymer, type of stabilizer, pH, and compounding ingredients. It is usually advisable to use softened or deionized water for all latex work, unless adequate technical control is developed for use of raw water for a particular process.

Viscosity and Total Solids These properties are determined primarily by the particle size of each latex; including its adsorpted em ulsifier and water film, they are influenced by type and amount of emulsifier, electrolyte content, and temperature.

Table II. Variation of Latex Surface with Particle Diameter According to B. M. C. Zwicker(6)

Hypothetical latices of uniform particle size; polymer specific gravity = 1.0

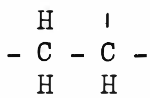
Particle Diameter (Microns[a])	Number of Polymer (per kg of polymer)	Total Surface (Sq.m. per kg) polymer	Theoretical Me. Soap (per 100 parts) polymer[b]
0.02	2.39×10^{20}	300,000	236
0.06	8.84×10^{18}	100,000	78.6
0.02	2.39×10^{17}	30,000	23.6
0.60	8.84×10^{15}	10,000	7.9
2.00	2.39×10^{14}	3,000	2.4
6.00	8.84×10^{12}	1,000	0.8

a: 1 Micron = 10,000 A b: Theoretical milliequivalent of saturated soap required for condensed monomolecular film per hundred parts of polymer solids.

CHEMISTRY OF SYNTHETIC LATICES

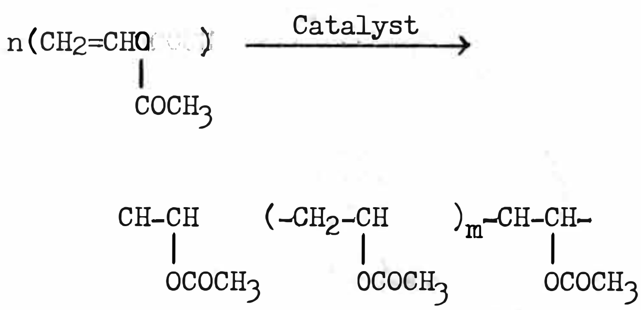
Chemical Constitution

Vinyl polymers and copolymers - Vinyl resins include a large number of compounds all of which contain this group:



This family includes several types which differ from each other only as to the nature of the atom or group which is linked to the vinyl radical.

Polyvinyl acetate ($CH_2CHOCOCH_3$) is a product of the reaction of acetylene and acetic acid in the presence of a catalyst. Addition polymerization yields a linear thermoplastic resin.(7,8)



Acrylic copolymers - The acrylic family embraces all products formed by the polymerization of monomers which are derivatives of acrylic acid, $CH_2{=}CHCOOH$.

Acrylonitrile is known as nitrile rubbers, Buna N, It consists of copolymers of butadiene and acrylonitrile. Properties of these copolymers can be modified at will by changing the ratio of butadiene to acrylonitrile. To commercial polymers contain about 20, 30, 40 percent of acrylonitrile. (9) The formation of acrylonitrile-butadiene can be illustrated by the following equations: (10)

Ethylene Oxide   Acrylonitrile

$$CH_3CH_2CH_2CH_3 + CH_3CH_2CH{=}CH_2 \longrightarrow CH_2{=}CH{-}CH{=}CH_2 \xrightarrow{\text{Acrylonitrile}}$$

Butane   Butylene   Butadiene

$$(-CH_2-CH{=}CH-CH_2CH_2\underset{CN}{CH}-)_n$$

Acrylonitrile 1,3 Butadiene

Acrylic Resins - Acrylate monomers may be formed from ethylene cyanohydrin. The polymer is the result of an addition polymerization of the monomer. (11) In the period of 1900-1902, Röhm and von Pechmann investigated the polymerization of methyl acrylate under the influence of metallic sodium and showed dimerization. (12)

$$CH_2{=}CH_2 \xrightarrow{HOCl} HOCH_2CH_2Cl \xrightarrow{NaCN} \underset{OH}{CH_2}CH_2CN$$

Ethylene
Cyanohydrin

$$\xrightarrow[H_2SO_4]{ROH} CH_2{=}CHCOOR$$

Acrylate monomer

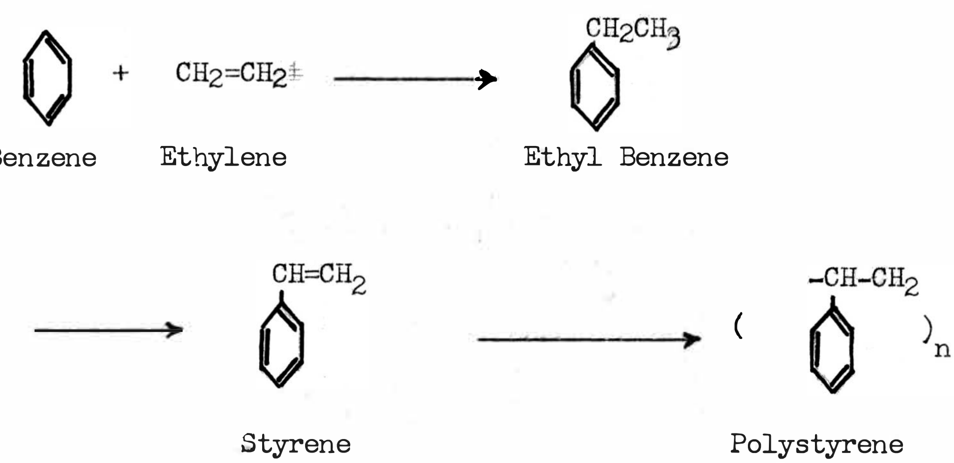
$$2\ CH_2{=}CH\cdot(COOCH_3) \longrightarrow CH_3\cdot CH(COOCH_3)\cdot CH{=}CH\cdot COOCH_3$$

(Stable)

Polyethylene - The empirical formula of polyethylene is $(CH_2)_n$ which consists of carbon 85.7% and hydrogen 14.3%. Polyethylene is formed by addition polymerization of ethylene at a pressure greater than 1200 atmosphere and at a temperature of 100-300 C. A lower pressure (less than 500 atm) can be used of a catalyst such as oxygen (less than 3 percent) or benzyl peroxide is added to the ethylene. (13,14)

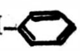
Partial crystallinity is the most important feature of the physical structure of polyethylene. A polyethylene has a partly crystalline, partly amorphous structure. It shows a gradual change to completely amorphous molten state as the temperature is increased. Crystallinity is modified with the variation in the extent of chain branching. Figure 2 shows the interrelation of chain length, crystallinity, and the nature of the polymers.(14) Normal commercial polyethylene contains about one methyl group for each 30 methylene units, and since the average chain length is around 2,000 there are about 70 methyl groups in each molecule. (13)

Polystyrene-Butadiene Monomeric styrene is converted to the polymer by means of heat, light or catalyst, or combination of these.(15)



When butadiene and styrene are used as co-polymers, the product is known as Buna S. (9) The original product of polystyrene-butadiene, developed as substitute for natural rubber, was high in butadiene, namely 72 percent. By reducing the quantity of butadiene to about 40 percent and increasing the quantity of styrene to about 60 percent, a new product was obtained and used successfully by the coating industry. Complete elimination of butadiene leads to straight polystyrene latices which have found their place in the paper industry. The chemical structure is $CH_2{=}CHCH{=}CH_2$.

The structure of the copolymer is assumed as: (16)

$$-CH_2CH{=}CHCH_2CH_2CH_2-CH-$$ 

Physical and Chemical Properties of Synthetic Latices   A summary of the physical and chemical properties of synthetic latices is shown in Table III.

BLENDING LATEX WITH OTHER ADHESIVES

Casein and Soya Protein   Styrene-butadiene latex is compatible with protein solution dispersed with any monovalent alkali. Generally, it is used with protein solutions made with caustic soda, sodium carbonate, ammonia, or a combination of any of these. When a protein solution is added to the concentrated latex, excessive thickening results. However, if the protein is first blended

with the pigment slip and the latex is added last, the viscosity of the pigmented coating is lower than when protein is used alone as the adhesive. The effect of latex on the coating characteristics is noted when only small amounts of protein are replaced. Lower viscosity is readily obtained, but the rheology of the system needs further study to determine the mechanics of this effect. In general, a replacement of 20 to 50 percent of the adhesive with latex gives the desired improvement in paper properties. A definite increase in flexibility, smoothness, gloss, and printing quality may be obtained with a 20 percent replacement. A 50 percent replacement results in an excellent folding sheet with superior smoothness, water resistance, lack of curl, and printing qualities. (17)

Starch Latex is compatible with corn starch, but the degree of compatibility varies with the type and degree of modification of the starch. (17)

Soya Flour Soya flour contains a large quantity of carbohydrates, some of which is undesirable. Latex is compatible with soya flour if it is stabilized with a small amount of isolated protein before mixing. (17)

Reactive Pigments Pigment containing a relatively large amount of free polyvalent metal ions, such as calcium carbonate and satin white, must be buffered with a complex phosphate. The satin white should be adjusted to pH as close to 7.0 as possible to minimize the free metal ion content.

For normal pigments, about 0.2 percent phosphate based on o. d. pigment protects the latex very well. It should be emphasized that phosphate may not be necessary with many clays, but it must always be used with calcium carbonate. When satin white is used, it may be necessary to increase the amount of complex phosphate to 0.5 percent based on the dry pigment. The phosphates which are recommended to be used to disperse the pigments are tetrasodium pyrophosphate, sodium hexametaphosphate, sodium tetraphosphate, or one of the septaphosphates. (17)

Influence on Coating Color

Vinyl polymers and copolymers - In compounding vinyls, pigments must be selected cautiously. A pigment which acts as stabilizer for some other materials may act as a catalyst for deterioration of vinyls. Soluble dyestuffs are said in most cases to be unsatis-

factory since moisture might cause the coloring to be leached out. Inorganic pigments are generally safe to use for their inertness to vinyls. (7)

Polystyrene-Butadiene - The addition of small amount, two to five percent, of protein adhesive into polystyrene-butadiene will improve the stability of the blend of pigments and modifiers with polystyrene-butadiene, because of pigments and modifiers cause instability when used with the latex alone. (18)

Thermal oxidation is one of the characteristics of polystyrene. One of the main effects of oxidation of polystyrene is the change in color from light yellow to yellow, brown and black. An addition of an antioxidant will protect polystyrene from oxidation. (15)

Acrylates - It is suggested to keep the coating color blend to 60 percent total solids content. Reduced coverage and reduce gloss will be observed at lower solids. (19)

Influence on Rheological Properties   Unless the coating mixture has the proper flow properties, irregular transfer will result and wierd patterns will produced. (2)

As mentioned, when a protein solution is added to the concentrated latex, excessive thickening results. If the protein is first blended with the pigment slip and the latex is added last, the viscosity of the pigmented coating is lower than when protein is used alone as the adhesive. The effect of latex on the coating characteristics is remarkable when only small amounts of protein are replaced. Lower viscosity is readily obtained.

When latex is compounded with corn starch, the actual viscosity of a coating may be reduced by the latex, while the thixotropic characteristics of the color are not affected.

The addition of a protein solution to the latex to stabilize it, should not cause a significant increase in viscosity.
The stabilized latex can then be added to the starch coating color without danger of coagulation during the coating operation. Most starch can be used with stabilized latex without causing coagulation of the latex.

It has been observed that latex thins out protein coating colors made with standard grades of coating clay. Latex is said to cause thixotropy in a color containing very fine particle size clay. It has been also observed that the use of latex in higher solids starch coating may increase or decrease the viscosity depending on the grade of clay used. (17)

PART II. EXPERIMENTAL WORK

EXPERIMENTAL DESIGN

The subject of this project was to evaluate and compare the adhesive strength of various latices used as binding agents in coating color applied to a sheet of paper. There are many factors which will influence the properties of the coated sheets and the adhesion of the coating color to the base paper. Therefore, a standard formulation was used in all experiments with variation of the percentage of latex substitution as sole variable. The percentage of latex used to replace the casein in each formula were 25, 50, and 75 percent respectively. In addition, when it was necessary to adjust pH of the coating color, a small amount of sodium hydroxide was added.

The following steps of operation were planned:

1. Prepare master batches of clay slurry and casein solution separately.
2. Prepare low viscosity polyethylene emulsion by wax-to-water technique.

3. Adjust total solids content and pH of each coating color with and without latex and determine the number of the doctor rod to be used to produce uniform coat weight with different formulations.

4. Determine the viscosity of the coating colors using Brookfield Synchro-Lectric Viscometer.

5. Coat wood base paper and bamboo base paper on wire side only and dry the coated sheets in an oven.

6. Evaluate the coated sheets as to their opacity, gloss, and brightness.

7. Evaluate the coated sheets after supercalendering as to their thickness, opacity, gloss, and brightness.

8. Determine the adhesive properties of the supercalendered sheets using the following methods:

   a. Dennison Standard Paper Testing Waxes

   b. Waldron Pick Tester (Dividson-Pomper)

   c. I. G. T. Tester.

METHODS AND EQUIPMENT USED

COMPOUNDING COATING COLOR

Preparation of Clay Slurry A master batch of 55 percent clay slurry was prepared for compounding coating color. The clay slip was sheared in a laboratory size Day Mixer at 73 to 75 percent for 20 to 30 minutes. Thereupon, a definite quantity of water was added to produce a solids content of 55 percent. At the beginning of shearing, a dispersing agent (0.3 percent) was added in form of a five percent solution. The formulation for the clay slurry is shown in Table IVa.

Preparation of Casein Solution A 20 percent casein solution was made with the aid of three percent sodium hydroxide based on the dry solids. The solution was prepared by first soaking casein in water for 15 minutes with agitation by adding the alkali and by raising the temperature of the mixture to 140 F (60 C). This temperature was maintained for a period of 20 minutes by means of water bath. The solution was then protected with 3.3 percent prese rvative based on dry casein solids. The formulation for the 20 percent casein solution is shown in Table IVb.

Preparation of Polyethylene Emulsion The only latex which had to be prepared in the laboraotry was polyethylene emulsion. A wax-to-water technique was used. The solid polyethylene was melted and oleic acid was added at a temperature from 100 to 150 C. Thereupon, morpholine was added at 120 to 130 C. Care was taken to avoid boiling of morpholine. The melt heated to 120 to 125 C was added to water at 95 to 98 C very slowly under fast agitation. As soon as emulsion was formed, it was cooled down to room temperature under a moderate agitation. The final solids content of the emulsion was determined. Detail of the formulation may be seen from Table V.

Preparation of Coating Color The required amount of clay slip and casein solution were weighed out separately. The casein solution was added slowly to the clay slip. After thoroughly blending clay and casein dispersions, latex was added in different quantities according to the formulation. The latex was added slowly and carefully. Neither antifoaming agent nor stabilizer was added. After the addition of latex, the total solids content

of the coating color was adjusted to 35 to 50 percent. Likewise, the pH value was brought to 8.5 to 9.5. As to the standard casein coating color, the blending was carried out by casein and clay.

The total solids content and the type of doctor rod needed were determined. The pH value and the viscosity of the mixture were recorded. To obtain maximum possible release of foam, the coating color was obtained by storing for at least 16 hours (overnight) before application to paper.

The formulations of all coating color have been listed in Table VI.

Coating and Drying The base paper was coated on the wire side with the coating color by means of the doctor rod draw-down method. The coat weight was controlled to yield 14 plus/minus 2 pounds per 25" x 38"-500 ream.

The coated paper was dried in an oven at 105 C for five minutes.

Supercalendering Coated Sheets The coated sheets were conditioned at 73 F and 50 percent relative humidity and were supercalendered at an air pressure of 30 pounds (that is, in this case of the supercalender, it was 1320 pounds per lineal inch at nip), by using the laboratory supercalender. The sheets were passed through the nip of the calender four times. The supercalendering conditions have been shown in Table VII.

DETERMINING PHYSICAL PROPERTIES

To determine the thickness and optical properties of the body stock and coated sheets, the following instruments were used:

Thickness	A caliper graduated to one-tenth point (0.0001 in.) to determine the thickness in accordance with TAPPI Standard T 411 m. was used.
Brightness	A Photovolt brightness tester was employed to determine the brightness of the papers in accordance with TAPPI Standard T 452 m.
Gloss	A 75° angular photovolt gloss meter was used to determine the gloss in accordance with TAPPI Standard T 424 m and T 480 m.

Opacity A Bausch and Lomb opacimeter was used to determine the opacity of papers in accordance with TAPPI Standard T 425 m.

EVALUATION OF ADHESIVE VALUES

The adhesive values of the coating color containing either straight casein or partially replaced polymers were evaluated by determining the resistance of coated sheets to "picking". The results of the coating color compounding latex were compared with the values obtained for standard casein color. Three methods were used in this project:

Dennison Standard Paper Testing Wax - The number of wax used without pick was recorded as "pass" number. The type of pick observed with a higher number of wax was also recorded.

Waldron Pick Tester - This instrument, also called Dividson-Pomper pick tester, was used with number six IPI Tack Ink at 88 F. Constant temperature of the printing surface was maintained by the thermostat for the bed plate. By means of changing speed under the same pressure between cylinder and the bed plate, the surface speed was determined at which picking occurred.

I. G. T. Tester - This tester permits to determine the degree of bonding and its initial failure by application of ink at progressively increasing speed. IPI Tack Ink used in this procedure was number 4 grade. The results obtained were expressed in centimeter per minute, but they have been converted into feet per minute in this report.

PRESENTATION OF RESULTS

PHYSICAL PROPERTIES OF COATING COLOR AND LABORATORY COATED PAPERS

Viscosity of Coating Color The viscosity of different coating colors has been listed in Table VIII.

Coat Weight The coating weight of the coated sheets has been shown in Table IX (wood base paper) and Table X (bamboo base paper).

Brightness The brightness of coated sheets has been shown in the following tables:

Table IX (Unsupercalendered, wood base paper)
Table X (Unsupercalendered, bamboo base paper)
Table XI (Supercalendered, wood base paper)
Table XII (Supercalendered, bamboo base paper)

A comparison of brightness obtained of the supercalendered sheets with straight casein color and with the replaced latex color

has been shown as Figure 3 (wood base paper) and Figure 4 (bamboo base paper).

Opacity   The opacity of coated sheets has been listed in following tables:

Table IX	(Unsupercalendered, wood base paper)
Table X	(Unsupercalendered, bamboo base paper)
Table XI	(Supercalendered, wood base paper)
Table XII	(Supercalendered, bamboo base paper)

A comparison of opacity of sheets produced either with plain casein or with casein-latex mixture has been shown in Figure 5 (wood base paper) and Figure 6 (bamboo base paper).

EVALUATION OF ADHESIVE VALUES OF COATING COLOR BY MEANS OF PRINTABILITY

Straight casein coating color was used as a standard in evaluating the adhesive value of the coating colors. The results have been shown in the following figures and tables:

Figures 9 and 10	(Maximum wax number without pick by Dennison Wax testing method)
Tables XIII and XIV	(Pick resistance test by Dennison Wax testing method)
Figures 11 and 12	(Pick start by Waldron Pick tester)
Tables XV and XVI	(Pick resistance test by Waldron Pick tester)

Figures 13 and 14   (Pick start by I. G. T. Tester)

Tables XVII and XVIII (Pick resistance test by I. G. T. Tester)

DISCUSSION OF RESULTS

VISCOSITY OF COATING COLOR

Acrylates and polystyrene-butadiene latices gave the greatest decrease in viscosity when substituting casein in coating color. Vinyl acetate and polyethylene gave, in general, an increase in viscosity, though they showed a tendency to decrease viscosity at 75 percent replacement.

All formulations were thixotropic; thus, increased rate of shear resulted in decreased viscosity.

THICKNESS OF SUPERCALENDERED COATED SHEETS

The thickness of the finished coated sheets of wood base paper has been found to be less than that of the raw stock itself, and the thickness of the supercalendered coated sheets with bamboo base paper has been found to be more than that of the base paper. These results were due to the difference in density of the base stock.

GLOSS OF SUPERCALENDERED COATED SHEETS

In case of coated wood body stock, at 25 percent replacem ent of casein with latex, only the coating color containing vinyl acetate gave a

gloss value higher than that for straight casein. The remaining four latices yielded lower gloss. Thus, highest gloss was obtained with a vinyl acetate-casein blend, followed by straight casein, polystyrene-butadiene, acrylates, acrylonitrile-butadiene, and finally polyethylene.

When casein was replaced by latex to the extent of 50 percent, vinyl acetate produced again highest gloss, followed by polyethylene, polystyrene-butadiene, acrylonitrile-butadiene, straight casein and finally acrylates.

At 75 percent replacement of casein by latices, all coating colors containing synthetics produced more gloss than straight casein

In case of coated bamboo base paper, at 25 percent substitution of casein by synthetic polymers, none of the coating colors produced as high a percentage of gloss as straight casein.

At 50 percent replacement of casein by latex, only vinyl acetate yielded a higher gloss than that of a plain casein formulation.

At 75 percent replacement of casein by latex, vinyl acetate produced highest gloss followed by acrylonitrile-butadiene, and then closely by postyrene-butadiene. Formulations containing acrylates and polyethylene yielded lower gloss than straight casein formulation.

BRIGHTNESS OF SUPERCALENDERED COATED SHEETS

In case of wood base paper, all synthetics caused a moderate loss in brightness at 25 percent and 50 percent substitution of casein in the

coating color. At 75 percent substitution, vinyl acetate caused a slight increase in brightness beyond plain casein bound coatings.

In the case of bamboo base paper, all coatings containing synthetics were lower in brightness than straight casein bound coatings.

OPACITY OF SUPERCALENDERED COATED SHEETS

In case of coated wood base paper, generally, straight casein bound coating produced more opacity than casein-latex blends

There was one exception, in the case of 75 percent substitution of casein by vinyl acetate latex, the coated sheet showed slightly higher opacity than the straight casein formulation.

Vinyl acetate reduced opacity to a limited extent in formulation containing 25 percent and 50 percent of the synthetic polymer and 75 and 50 percent casein.

Acrylates reduced opacity to a considerable extent, particularly at 25 percent and 50 percent substitutions of the casein binder.

In case of coated bamboo base paper, vinyl acetate at 25 percent and 50 percent substitutions of casein produced higher opacity than straight casein. Acrylonitrile-butadiene reduced opacity to a considerable extent at 25 and 50 percent substitutions of the casein binder. At 75 percent substitution, acrylonitrile-butadiene-casein, polystyrene-butadiene

casein mixtures and straight casein gave practically the same opacity to coated sheets.

Acrylates reduced opacity successively with the higher substitutions of casein in color formulations.

Polyethylene yielded nearly a same opacity as acrylates, and reduced opacity at 75 percent replacement to a considerable extent.

ADHESIVE VALUE OF SUPERCALENDERED COATED SHEETS

Three methods were used to evaluate the bonding strength of the coated sheets. All tests were run with sheets conditioned at 73 F and 50 percent humidity as specified in TAPPI Standard T 402 m.

Dennison Wax Pick Test The thermoplastic nature of the synthetic latices influenced the results by the Dennison Wax Pick test. Other methods had to be employed to achieve at valid results.

Waldron Pick Test Vinyl acetate showed lowest bonding strength in all coating formulations. This was true for wood and bamboo base papers.

Polyethylene had low bonding strength at 50 and 75 percent substitutions of casein in coating colors. When 25 percent of the casein in a coating color was substituted by polyethylene, the bonding strength seemed to be slightly above the valur found for straight casein.

Acrylonitrile-butadiene and polystyrene-butadiene showed regularly bonding strength in excess of the value established for straight casein.

By far the best bonding strength was shown by acrylates.

I. G. T. Print and Pick Test The tests carried with the I.G.T. print and pick tester tended to confirm the results produced by means of the Waldron Pick tester.

Acrylates showed highest bonding strength, followed by acrylonitrile-butadiene and polystyrene-butadiene.

Polyethylene showed bonding strength at 50 and 75 percent substitutions of casein; at 25 percent substitution, the bonding strength was similar to straight casein.

Vinyl acetate exhibited weak adhesive strength.

CONCLUSIONS

ADHESIVE VALUES

Of five synthetic polymer latices used to replace partially casein pound by pound in a coating color, acrylates possessed the highest adhesive value.

Acrylonitrile-butadiene and polystyrene-butadiene exceeded the adhesive value of casein, but were far below the adhesive value of acrylates.

Polyethylene used in blends consisting of 75 percent casein and 25 percent of the synthetic matched the adhesive value of straight casein or even surpassed it slightly. Mixture of equal parts of casein and polyethylene as well as blend of 25 percent casein and 75 percent polyethylene showed low adhesive values.

Vinyl acetate emulsions gave the lowest adhesive values of all synthetic polymers tested.

OPTICAL PROPERTIES

All synthetic polymers with exception of vinyl acetate yielded lower brightness values than casein used as binder for paper coatings. Vinyl acetate surpassed casein in a few formulations and matched casein in other cases.

All synthetic polymers with exception of vinyl acetate yielded lower opacity value than casein used as binder for paper coating. Vinyl acetate surpassed casein in several form latices and was slightly lower in a few other cases

Vinyl acetate was the best producer of gloss of all synthetics tested. In general, the gloss was for in excess of the value produced by straight casein bound coating colors

Conversely, acrylates, in general, did not produce outstanding gloss and were inferior in this respect to straight casein formulation.

The other three polymers produced good gloss in blends of 25 percent casein and 75 percent latex whereas smaller quantities of the latex did not surpass the gloss produced by straight casein formulation.

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Table 1. Classification of Commercial Flexible Latex by Polymer Composition According to B. M. G. Zwicker (6)

Class and Group	Polymer Description
I. Acrylic Rubbers	Polyacrylic ester, Acrylic Copolymer
II. Butadiene Rubbers, Acrylic Copolymers, Styrene Copolymer	Acrylonitrile, Acrylonitrile Comonomer, Medium Styrene, BD-Styrene, Polybutadiene
III. Chloroprene Rubbers	Chloroprene Polymer
IV. Isobutylene Rubbers	Polyisobutylene Disperser
V. Polysulphide Rubbers	Polyethylene polysulphides
VI. Acrylic Plastics	Copolymer, Acrylic type resin and plastic
VII. Polyamide	Polyamine-polyfatty acids
VIII. Polyesters	Modified Alkyd
IX. Polyfluorinated Plastics	Polytrifluoroethylene and polytetrafluorochloroethylene
X. Styrene Plastics; Unplasticized, Plasticized, and Copolymers	Polystyrene, Butadiene
XI. Vinyl Butyral Plastics	Plasticizer
XII. Vinyl Chloride Plastics; Unplasticized, Pre-plasticized, and Copolymers	
XIII. Vinyl Ester Plastics (Polyvinyl Acetate)	
XIV. Vinylidene Chloride Plastics	
XV. Rubber Plastic Blends; Nitrile-polyvinyl Chloride, Nitrile-styrene Acrylonitrile; Styrene Acrylonitrile; Styrene Rubber; Styrene Plastic	
XVI. Miscellaneous	Newly developed and unknown composition latices

Table III. Physical and Chemical Prope ties of Synthetic Latices

Class and Group	Total Solids percent	Stable pH Range	Average Particle Size, Microns	Particle Charge	Specific Gravity of Solid (Gum) at 20/20 C	Reflective Index of Solid (Gum) n_D	Film Properties: Strength	Film Properties: Clarity	Used as Adhesive: Effectiveness of Bond with Paper	Used as Adhesive: Bonding Classification
Acrylates	28 46	3.5 6.0-6.5	Less than 1	Anionic	1.054	1.48	Methyl-methy-Acrylate: Brit-tle films Ethyl Acrylate: Flows at moder-ate temperature, Flexibility, Light resistance	Extreme Clarity	Excellent	Solvent released fused by heating
Acrylonitrile-Butadiene	27-54	over 8.5	0.06-0.18	Anionic	0.96-1.00	1.521	Brittle films, Water resistance, Chemical resist-ance, Flexibility	Clarity	Excellent	Solvent released fused by heating
Polyethylene	30-40	Stable in com-plete absence of oxy-gen at temper-ature up to 290 C	-	-	0.92-0.93	1.51	Heat resistance, Flexibility over wide temperatu-re range	Translu-cent to opa-que	Fair	Solvent released fused by heating
Polustyrene-Butadiene	48	9-10.5	0.20	Anionic	1.01	1.567	Brittle films, Water resistance, Chemical resist-ance, Flexibility	Clarity	Excellent	Solvent released fused by heating
Vinyl Acetate	60	4.5-5.0	Less than 1	Anionic	1.104	1.45-1.47	Resistance to weak acids and weak alkalies only, Soluble in many organic sol-vents, Slow burning rate	High trans-paren-cy	Fair	Solvent released fused by heating

Table IVa. Formulation of Clay Slurry

	Parts	Dry Weight, g	Wet Weight, g
Clay[1]	100	100	100.5
Dispersing Agent[2]	0.3	0.3	
Water (for shearing)			333.5
(for dilution)			484.5
Total solids content, percent		55	

(1) HT Clay, unpredispersed, moisture content = 0.51 percent
(2) Tetrasodium pyrophosphate, based on o.d. clay

Table IVb. Formulation of Casein Solution

	Parts	Dry Weight, g.	Wet Weight, g
Casein[1]	100	100	
Sodium hydroxide	4	4	
Preservative[2]	3.3	3.3	
Water			256.7
Total solids content, percent		20	

(1) Argetine Casein
(2) Dowicide G, applied as 20 percent solution

Table V. Formulation of Polyethylene Emulsion by Wax-to Water Technique

Polyethylene[1]	30 parts
Oleic Acid	6 parts
Morpholine	6 parts
Water	100 parts

Final emulsion: Total solids content - by calculation 25.33 percent
by determination 24.11 percent
Brookfield viscosity, at 25.3 C - in centipoises

Spindle Number	100 r.p.m.	50 r.p.m.
1	54.7	39.4
2	64.4	48.8

(1) A-C Polyethylene 629

Table VI. Formulations of Coating Color

Coating Color Number	Clay[1] Parts	Dispersing Agent[2] for Clay Parts	Casein[3] in Color Parts	Preservative for Casein[4] Parts	Composition Identification of Latex: Classification	Composition Identification of Latex: Parts in Color	Composition Identification of Latex: Latex Solids percent	Completed Coating Color[6]: Water in Color Parts	Completed Coating Color[6]: Sodium Hydroxide for final pH g (5)	Completed Coating Color[6]: Hydrogen-Ion Concentration pH	Total Solids Content: Calculated percent	Total Solids Content: Determined percent
101	100	0.3	16	3.3	-	-	-	176.2	-	7.58	40.0	41.61
102	100	0.3	12	2.48	Vinyl Acetate	4	59.6	167.37	-	7.71	40.94	41.45
103	100	0.3	8	1.65	Vinyl Acetate	8	59.6	129.08	-	7.32	47.33	48.01
104	100	0.3	4	0.825	Vinyl Acetate	12	59.6	115.79	-	7.21	50.04	50.75
105	100	0.3	12	2.48	Acrylates	4	46	203.52	0.33	8.90	36.26	36.84
106	100	0.3	8	1.65	Acrylates	8	46	185.56	0.40	9.08	38.42	38.52
107	100	0.3	4	0.825	Acrylates	12	46	149.25	0.35	9.30	42.08	42.28
108	100	0.3	12	2.48	Acrylonitrile-Butadiene	4	50.3	174.12	0.187	9.05	39.96	40.21
109	100	0.3	8	1.65	Acrylonitrile-Butadiene	8	50.3	146.08	0.147	8.82	44.24	44.09
110	100	0.3	4	0.825	Acrylonitrile-Butadiene	12	50.3	130.37	0.133	8.78	47.06	47.48
111	100	0.3	12	2.48	Polystyrene-Butadiene	4	48	158.77	0.48	9.08	41.24	42.17
112	100	0.3	8	1.65	Polystyrene-Butadiene	8	48	148.86	0.44	9.01	43.83	43.74
113	100	0.3	4	0.825	Polystyrene-Butadiene	12	48	126.03	0.40	8.95	48.01	47.87
114	100	0.3	12	2.48	Polyethylene	4	24.11	201.70	0.152	8.82	37.70	39.45
115	100	0.3	8	1.65	Polyethylene	8	24.11	168.10	0.144	8.80	40.80	43.05
116	100	0.3	4	0.825	Polyethylene	12	24.11	147.90	0.112	8.75	43.94	46.28

(1) HT Clay, unpredispersed
(2) Tetrasodium Pyrophosphate, based on o.d. clay
(3) Argentina Casein
(4) Dowicide G
(5) Sodium hydroxide solution applied as four percent concentration by weight
(6) Viscosities listed on Table VIII separately

Table VII. Supercalendering Operation

Coating Color Number	Surface Temperature of Rolls, deg.F				Pressure Between Rolls	
	Steel Rolls(1)		Cotton Filled Rolls(2)		Guage Reading	Linear Pressure
	At the Beginning	At the End	At the Beginning	At the End	psig	pound per lineal inch at nip
101	95	95	105	106	30	1320
102	95	98	106	109	30	1320
103	98	99	110	111	30	1320
104	99	99	111	112	30	1320
105	99	99	112	114	30	1320
106	99	102	114	116	30	1320
107	102	102	116	116	30	1320
108	103	104	114	115	30	1320
109	104	104	115	115	30	1320
110	104	104	115	117	30	1320
111	104	106	112	114	30	1320
112	106	108	114	117	30	1320
113	108	109	117	115	30	1320
114	109	109	115	117	30	1320
115	109	109	117	117	30	1320
116	109	109	117	119	30	1320

(1) Average: 102.5 F
Maximum: 109.0 F
Minimum: 95.0 F

(2) Average: 113.8 F
Maximum: 119.0 F
Minimum: 105.0 F

Table VIII. Viscosities of Coating Color in Various Replacements of Latices

Coating Color Number	Clay Parts	Casein Parts	Latex Composition Identification: Classification	Latex Composition Identification: Parts	Total Solids Content: Calculated percent	Total Solids Content: Determined percent	Temperature of Color* deg C	Brookfield Viscosities, Centipoises: Spindle Number 2, 100 r.p.m.	Spindle Number 2, 50 r.p.m.	Spindle Number 3, 100 r.p.m.	Spindle Number 3, 50 r.p.m.
101	100	16	-	-	40	41.61	23.6	376	456	-	-
102	100	12	Vinyl Acetate	4	40.94	41.45	24.0	263.8	318.8	-	-
103	100	8	Vinyl Acetate	8	47.33	48.01	24.0	out of scale	692	-	-
104	100	4	Vinyl Acetate	12	50.04	50.75	24.0	379.2	633.4	-	-
105	100	12	Acrylates	4	36.26	36.84	24.0	out of scale	out of scale	out of scale	1914
106	100	8	Acrylates	8	38.42	38.52	24.0	out of scale	436	419.6	417.6
107	100	4	Acrylates	12	42.08	42.28	24.0	211.5	187.2	205.7	201
108	100	12	Acrylonitrile-Butadiene	4	39.96	40.21	24.0	out of scale	673	594	662
109	100	8	Acrylonitrile-Butadiene	8	44.24	44.09	24.0	out of scale	460.32	409	466.4
110	100	4	Acrylonitrile-Butadiene	12	47.06	47.48	24.0	281.52	330.08	291	319.2
111	100	12	Polystyrene-Butadiene	4	41.24	42.17	24.5	out of scale	out of scale	867	1238
112	100	8	Polystyrene-Butadiene	8	43.83	43.74	24.5	259.2	307.2	258.8	285.6
113	100	4	Polystyrene-Butadiene	12	48.01	47.87	24.5	166.8	170.88	155.6	173.6
114	100	12	Polyethylene	4	37.70	39.45	27.5	out of scale	574.56	547	615.6
115	100	8	Polyethylene	8	40.80	43.05	27.5	out of scale	out of scale	757.8	858.8
116	100	4	Polyethylene	12	43.90	46.28	27.5	out of scale	693.1	636.2	730

*Temperature of color when determining

Table IX. Physical Properties of Uncalendered Coated Sheets

(Wood Base Paper)**

Coating Color Number	Doctor Rod Number Applied	Total Solids of Coating Color percent***	Basis Weight, lb. 25 x 38 - 500 ream			Caliper, 1/1000 in.			Gloss 75°Angular-Photovolt		Brightness Photovolt-Brightness			Opacity Bausch-Lomb Opacimeter Contrast Ratio		
			Before Coating	After Coating	Coating Weight	Before Coating	After Coating	Coating Thickness	Before Coating	After Coating	Before Coating	After Coating	Difference	Before Coating	After Coating	Difference
101	15	41.61	50.3	65.2	15.1	4.20	4.92	0.72	12.1	12.86	68	76.2	+8.2	91.8	93.4	+1.60
102	17	41.45	50.3	64.6	14.3	4.20	4.86	0.66	12.1	11.60	68	77.9	+9.9	91.8	93.58	+1.78
103	17	48.01	50.3	63.0	12.7	4.20	4.96	0.76	12.1	14.74	68	77.9	+9.9	91.8	93.96	+2.16
104	17	50.75	50.3	63.9	13.6	4.20	5.15	0.95	12.1	14.44	68	80.0	+12.0	91.8	95.64	+3.84
105	11	36.84	50.3	64.4	14.1	4.20	5.06	0.86	12.1	8.86	68	73.8	+5.8	91.8	92.22	+0.42
106	17	38.52	50.3	64.1	13.8	4.20	5.14	0.94	12.1	9.90	68	74.6	+8.6	91.8	93.74	+1.94
107	15	42.28	50.3	63.7	13.4	4.20	5.21	1.01	12.1	11.38	68	74.7	+6.7	91.8	93.6	+1.80
108	9	40.21	50.3	63.3	13.0	4.20	5.03	0.83	12.1	8.48	68	74.2	+6.2	91.8	91.98	+0.18
109	9	44.09	50.3	61.6	11.3	4.20	5.11	0.91	12.1	11.34	68	75.0	+7.0	91.8	92.8	+1.0
110	9	47.48	50.3	62.0	11.7	4.20	5.07	0.87	12.1	10.94	68	75.0	+7.0	91.8	92.22	+0.42
111	10	42.17	50.3	62.9	12.6	4.20	4.82	0.62	12.1	10.54	68	76.0	+8.0	91.8	94.88	+3.08
112	10	43.83	50.3	63.1	12.8	4.20	4.90	0.70	12.1	12.88	68	76.0	+8.0	91.8	93.10	+1.30
113	9	48.01	50.3	60.6	12.3	4.20	5.13	0.93	12.1	12.32	68	76.5	+8.5	91.8	93.26	+1.46
114	15	39.45	50.3	63.6	13.3	4.20	5.27	1.07	12.1	8.80	68	73.0	+5.0	91.8	93.02	+1.32
115	11	43.05	50.3	63.7	13.4	4.20	4.96	0.76	12.1	9.72	68	73.06	+5.06	91.8	92.56	+0.76
116	9	42.68	50.3	63.0	12.7	4.20	5.13	0.93	12.1	11.92	68	72.0	+4.0	91.8	92.38	+0.58

*** Total solids content based on determined figures

** Wood base paper made by Allied Paper Company, Kalamazoo, Michigan, U.S.A., as commercial coating base stock composed of bleached softwood sulphite, bleached hardwood kraft, and unbleached softwood ground

Table X. Physical Properties of Uncalendered Coated Sheets
(Bamboo Base Paper)*

Coating Color Number	Doctor Rod Number Applied	Total Solids of Coating Color percent**	Basis Weight, lb. 25 x 38 - 500 ream			Caliper, 1/1000 in.			Gloss 75° Angular-Photovolt		Brightness Photovolt-Brightness			Opacity Bausch-Lomb Opacimeter Contrast Ratio		
			Before Coating	After Coating	Coating Weight	Before Coating	After Coating	Coating Thickness	Before Coating	After Coating	Before Coating	After Coating	Difference	Before Coating	After Coating	Difference
101	15	41.61	38.1	55.1	17.0	2.98	3.87	0.89	11.82	12.02	71.8	77.8	+6.0	76.8	91.92	+15.12
102	17	41.45	38.1	52.5	14.4	2.98	3.86	0.88	11.82	11.02	71.8	77.0	+5.2	76.8	89.10	+12.10
103	17	48.01	38.1	50.9	12.8	2.98	4.34	1.36	11.82	14.84	71.8	77.2	+5.4	76.8	93.80	+17.00
104	17	50.75	38.1	57.6	19.5	2.98	4.41	1.43	11.82	14.50	71.8	79.8	+8.0	76.8	93.08	+16.28
105	11	36.84	38.1	51.0	12.9	2.98	3.95	0.97	11.82	6.96	71.8	75.3	+3.5	76.8	88.12	+11.32
106	17	38.52	38.1	52.8	14.7	2.98	4.11	1.13	11.82	8.74	71.8	75.1	+3.3	76.8	89.14	+12.34
107	15	42.28	38.1	54.0	15.9	2.98	3.96	0.98	11.82	11.36	71.8	75.3	+3.5	76.8	87.5	+10.70
108	9	40.21	38.1	49.3	11.2	2.98	3.87	0.89	11.82	7.94	71.8	74.2	+2.4	76.8	87.98	+11.18
109	9	44.09	38.1	54.1	16.0	2.98	3.52	0.54	11.82	10.44	71.8	74.5	+2.7	76.8	89.0	+12.20
110	9	47.48	38.1	53.7	15.6	2.98	3.92	0.94	11.82	11.30	71.8	75.7	+3.9	76.8	89.18	+12.38
111	10	42.17	38.1	53.8	15.7	2.98	4.09	1.11	11.82	9.54	71.8	76.0	+4.2	76.8	89.58	+12.78
112	10	43.83	38.1	53.8	15.7	2.98	4.04	1.06	11.82	11.80	71.8	77.0	+5.2	76.8	89.68	+12.88
113	9	48.01	38.1	53.7	15.6	2.98	4.11	1.13	11.82	11.94	71.8	77.0	+5.2	76.8	88.80	+12.00
114	15	39.45	38.1	51.7	13.6	2.98	3.84	0.86	11.82	7.36	71.8	73.2	+1.4	76.8	88.16	+11.36
115	11	43.05	38.1	52.8	14.7	2.98	4.02	1.04	11.82	8.28	71.8	73.2	+1.4	76.8	88.76	+11.96
116	9	46.28	38.1	52.6	14.5	2.98	4.02	1.04	11.82	9.02	71.8	72.5	+0.7	76.8	88.32	+11.52

* Bamboo base paper made by Tatu Paper Mill, Taiwan Pulp and Paper Corporation, Formosa, as commercial simili paper (containing 20 percent bagasse pulp)
** Total solids content based on determined figures

Table XI. Physical Properties of Supercalendered Coated Sheets

(Wood Base Paper)

	Caliper 1/1000 in.			Brightness Photovolt-Brightness			Gloss 75° Angular Photovolt			Opacity B and L Opacimeter, Contrast Ratio		
Color No.	Before Calendering	After Calendering	Difference	Before Calendering	After Calendering	Difference	Before Calendering	After Calendering	Difference	Before Calendering	After Calendering	Difference
101	4.92	3.98	-0.94	76.2	74.14	-2.06	12.86	51.02	+38.16	95.3	93.8	-1.50
102	4.86	3.88	-0.98	77.9	73.20	-4.79	11.60	54.68	+43.08	93.58	93.26	-0.32
105	5.06	3.97	-1.09	73.8	72.70	-1.10	8.86	46.12	+37.26	92.60	91.80	-0.80
108	5.03	3.91	-1.12	74.2	72.60	-1.60	8.48	47.58	+39.10	91.98	89.54	-2.44
111	4.82	3.93	-0.89	76.0	73.22	-2.78	10.54	49.22	+38.68	94.88	91.02	-3.86
114	5.27	3.99	-1.28	73.0	71.90	-1.10	8.80	44.76	+35.96	93.02	91.34	-1.68
103	4.96	4.00	-0.96	77.9	73.48	-4.42	14.74	62.76	+48.02	93.96	92.43	-1.53
106	5.14	3.97	-1.16	74.6	72.76	-1.84	9.90	50.38	+40.48	93.74	92.05	-1.69
109	5.11	3.77	-1.34	75.0	72.78	-2.22	11.34	52.24	+40.90	92.80	89.81	-2.99
112	4.90	4.01	-0.89	76.0	72.86	-3.14	12.88	53.30	+40.42	93.10	91.89	-1.21
115	4.96	3.99	-0.97	73.06	69.94	-3.12	9.72	53.56	+43.84	92.56	91.39	-1.17
104	5.15	4.04	-1.11	80.0	74.82	-5.18	14.44	64.63	+50.19	95.64	94.13	-1.51
107	5.21	4.01	-1.20	74.7	72.26	-2.44	11.38	54.82	+43.44	93.60	91.11	-2.49
110	5.07	3.72	-1.35	75.0	71.72	-3.28	10.94	58.36	+47.42	92.22	90.94	-1.28
113	5.13	3.87	-1.26	76.5	73.28	-3.22	12.32	59.12	+46.80	93.26	90.71	-2.55
116	5.13	3.74	-1.39	72.0	68.82	-3.18	11.92	60.48	+48.56	92.38	90.40	-1.98

TABLE XII. Physical Properties of Supercalendered Coated Sheets

(Bamboo Base Paper)

	Caliper 1/1000 in.			Brightness Photovolt-Brightness			Gloss 75° Angular Photovolt			Opacity B and L Opacimeter, Contrast Ratio		
Color No.	Before Calendering	After Calendering	Difference	Before Calendering	After Calendering	Difference	Before Calendering	After Calendering	Difference	Before Calendering	After Calendering	Difference
101	3.87	3.31	-0.56	77.80	75.58	-2.22	12.02	53.25	+41.23	91.92	87.37	-4.55
102	3.86	3.30	-0.56	77.00	74.48	-2.52	11.02	47.50	+36.48	89.10	87.81	-1.29
105	3.95	3.09	-0.86	75.30	72.82	-2.48	6.96	40.56	+33.60	88.12	87.88	-0.24
108	3.87	3.12	-0.75	74.20	73.10	-1.10	7.94	40.76	+32.82	87.98	85.16	-2.82
111	4.09	3.37	-0.72	76.00	74.02	-1.98	9.54	48.78	+39.24	89.58	86.46	-3.12
114	3.84	3.57	-0.27	73.20	72.16	-1.04	7.36	38.50	+31.14	88.16	86.01	-2.15
103	4.34	3.42	-0.92	77.20	75.18	-2.02	14.84	55.84	+41.00	93.80	90.50	-3.30
106	4.11	3.41	-0.70	75.10	73.34	-1.76	8.74	47.18	+38.44	89.14	87.05	-2.09
109	3.52	3.16	-0.36	74.50	73.50	-1.00	10.44	48.80	+38.36	89.00	86.35	-2.65
112	4.04	3.37	-0.67	77.00	74.40	-2.60	11.80	53.00	+41.20	89.68	86.05	-3.63
115	4.02	3.47	-0.55	73.20	70.64	-2.56	8.28	46.64	+38.34	88.76	86.96	-1.80
104	4.41	3.50	-0.91	79.80	75.15	-4.65	14.50	63.34	+48.84	93.08	90.64	-2.44
107	3.96	3.37	-0.59	75.30	73.26	-2.04	11.36	50.44	+39.08	87.50	86.19	-1.31
110	3.92	3.38	-0.54	75.70	73.00	-2.70	11.30	58.85	+47.55	89.18	87.48	-1.70
113	4.11	3.47	-0.64	77.00	74.04	-2.96	11.94	58.54	+46.60	88.80	87.34	-1.46
116	4.02	3.22	-0.80	72.50	69.44	-3.06	9.02	51.26	+42.24	88.32	85.40	-2.92

Table XIII. Pick Resistance of Coated Sheets

- Dennison Wax Method -

(Wood Base Paper)

Substitution of Latex: 25 percent

Coating Color No.	101 (Standard)	102	105	108	111	114
Wax Number 5	-	NP	-	-	NP	NP
6	NP	NP(Pass)	-	-	NP(Pass)	NP(Pass)
7	NP(Pass)	VSP	-	-	HP	HP
8	SP	HP	-	NP	-	-
9	HP	-	NP	NP(Pass)	-	-
10	-	-	NP(Pass)	VSP	-	-
11	-	-	HP	SP	-	-
12	-	-	-	HP	-	-

Substitution of Latex: 50 percent

Coating Color No.	101 (Standard)	103	106	109	112	115
Wax Number 2	-	VSP	-	-	-	SP
3	-	HP	-	-	-	HP
4	-	-	-	NP	NP	-
5	-	-	-	NP(Pass)	NP(Pass)	-
6	NP	-	-	VSP	HP	-
7	NP(Pass)	-	NP	HP	-	-
8	SP	-	NP(Pass)	-	-	-
9	HP	-	SP	-	-	-
10	-	-	HP	-		-

Substitution of Latex: 75 percent

Coating Color No.	101 (Standard)	104	107	110	113	116
Wax Number 2	-	SP	-	-	VSP	HP
3	-	HP	-	-	SP	-
4	-	-	-	NP	HP	-
5	-	-	-	NP(Pass)	-	-
6	NP	-	-	VSP	-	-
7	NP(Pass)	-	NP	HP	-	-
8	SP	-	NP(Pass)	-	-	-
9	HP	-	SP	-	-	-
10	-	-	HP	-	-	-

Code: NP= No pick VSP= Very slight pick
SP= Slight pick HP= Heavy pick

Table XIV. Pick Resistance of Coated Sheets

- Dennison Wax Method -

(Bamboo Base Paper)

Substitution of Latex: 25 percent

Coating Color No.	101 (Standard)	102	105	108	111	114
Wax Number 5	-	NP	-	-	NP	NP
6	NP	NP(Pass)	-	-	NP(Pass)	NP(Pass)
7	NP(Pass)	SP	NP	-	SP	SP
8	HP	HP	NP(Pass)	-	HP	NP
9	-	-	SP	NP(Pass)	-	-
10	-	-	HP	HP	-	-

Substitution of Latex: 50 percent

Coating Color No.	101 (Standard)	103	106	109	112	115
Wax Number 2	-	-	-	-	-	VSP
3	-	-	-	-	-	SP
4	-	NP	-	-	NP	HP
5	-	NP(Pass)	-	NP	NP(Pass)	-
6	NP	SP	NP	NP(Pass)	HP	-
7	NP(Pass)	HP	NP(Pass)	SP	-	-
8	HP	-	SP	HP	-	-
9	-	-	SP	-	-	-
10	-	-	HP	-	-	-

Substitution of Latex: 75 percent

Coating Color No.	101 (Standard)	104	107	110	113	116
Wax Number 2	-	HP	-	-	-	HP
3	-	-	-	-	NP	-
4	-	-	-	NP	NP(Pass)	-
5	-	-	-	NP(Pass)	VSP	-
6	NP	-	-	VSP	HP	-
7	NP(Pass)	-	-	HP	-	-
8	HP	-	NP	-	-	-
9	-	-	NP(Pass)	-	-	-
10	-	-	HP	-	-	-

Code: NP=No pick VSP= very slight pick
SP=slight pick HP=Heavy pick

Table XV - Pick Resistance of Coated Sheets

- Waldron Pick Tester -

(Wood Base Paper)

Ink Used: IPI Tack Ink Graded Black Number 6
Two knots of ink applied to a 35 square inches area
Printing Surface Temperature: 88±2° F

Substitution of Latex: 25 percent

Coating Color No.	101 (Standard)	102	105	108	111	114
	Press Speed, f.p.m.					
Pick start at	160	100	360	280	340	240
VSP at	-	-	360	280	-	-
SP at	160	100	-	-	340	240
HP at	240	140	440	300	360	280

Substitution of Latex: 50 percent

Coating Color No.	101 (Standard)	103	106	109	112	115
	Press Speed, f.p.m.					
Pick start at	160	60	500	400	300	60
VSP at	-	-	-	-	-	60
SP at	160	-	500	400	-	80
HP at	240	100	560	480	300	120

Substitution of Latex: 75 percent

Coating Color No.	101 (Standard)	104	107	110	113	116
	Press Speed, f.p.m.					
Pick start at	160	0	560	320	240	40
VSP at	-	-	-	-	-	-
SP at	160	0	560	320	-	-
HP at	240	20	640	360	240	40

Code: VSP = Very slight pick SP = Slight pick HP = Heavy pick

Table XVI. Pick Resistance of Coated Sheets

- Waldron Pick Tester -

(Bamboo Base Paper)

Ink Used: IPI Tack Ink Graded Black Number 6
Two knots of ink applied to a 35 square inches area
Printing Surface Temperature: 88±2° F

Substitution of Latex: 25 percent

Coating Color No.	101 (Standard)	102	105	108	111	114
	Press Speed, f.p.m.					
Pick start at	160	140	480	360	300	120
VSP at	-	-	-	360	300	120
SP at	160	-	480	400	-	160
HP at	320	140	560	560	320	340

Substitution of Latex: 50 percent

Coating Color No.	101 (Standard)	103	106	109	112	115
	Press Speed, f.p.m.					
Pick start at	160	100	520	320	300	180
VSP at	-	-	520	-	300	180
SP at	160	100	-	320	340	-
HP at	320	140	560	560	360	220

Substitution of Latex: 75 percent

Coating Color No.	101 (Standard)	104	107	110	113	116
	Press Speed, f.p.m.					
Pick start at	160	20	400	320	160	40
VSP at	-	-	400	-	160	-
SP at	160	20	560	320	240	40
HP at	320	100	-	360	280	80

Code: VSP = Very slight pick SP = Slight pick HP = Heavy pick

Table XVII. Pick Resistance of Coated Sheets

- I. G. T. Tester Method -

(Wood Base Paper)

Ink Used: One milliliter of IPI Tack Ink Graded Black Number 4

Spring Load Applied: 35 kilograms

Substitution of Latex: 25 percent

Coating Color No.	101 (Standard)	102	105	108	111	114
	Printing Speed, f.p.m.					
Pick start at	325	256	551	256	384	305
Coating color off body stock at	-	-	-	-	-	-
VSP at	-	-	-	-	384	305
SP at	325	256	551	256	410	325
HP at	404	305	610	354	423	378

Substitution of Latex: 50 percent

Coating Color No.	101 (Standard)	103	106	109	112	115
	Printing Speed, f.p.m.					
Pick start at	325	177	511	404	358	118
Coating color off body stock at	-	-	511	-	-	-
VSP at	-	-	-	-	-	-
SP at	325	177	-	404	358	118
HP at	404	197	571	452	410	197

Substitution of Latex: 75 percent

Coating Color No.	101 (Standard)	104	107	110	113	116
	Printing Speed, f.p.m.					
Pick start at	325	0	620	393	315	0
Coating color off body stock	-	-	620	393	315	-
VSP at	-	-	-	-	-	-
SP at	325	-	649	423	354	-
HP at	404	0	807	512	384	0

Code: VSP = Very slight pick SP = Slight pick HP = Heavy pick

Table XVIII. Pick Resistance of Coated Sheets

- I. G. T. Tester -

(Bamboo Base Paper)

Ink Used: One milliliter of IPI Tack Ink Graded Black Number 4

Spring Load Applied: 35 kilograms

Substitution of Latex: 25 percent

Coating Color No.	101 (Standard)	102	105	108	111	114
	Printing Speed, f.p.m.					
Pick start at	285	291	405	384	364	315
VSP at	285	291	-	-	-	-
SP at	315	374	405	384	364	315
HP at	331	413	-	433	404	354

Substitution of Latex: 50 percent

Coating Color No.	101 (Standard)	103	106	109	112	115
	Printing Speed, f.p.m.					
Pick start at	285	217	532	276	390	138
VSP at	285	217	-	276	390	-
SP at	315	256	532	433	417	138
HP at	331	286	630	512	-	177

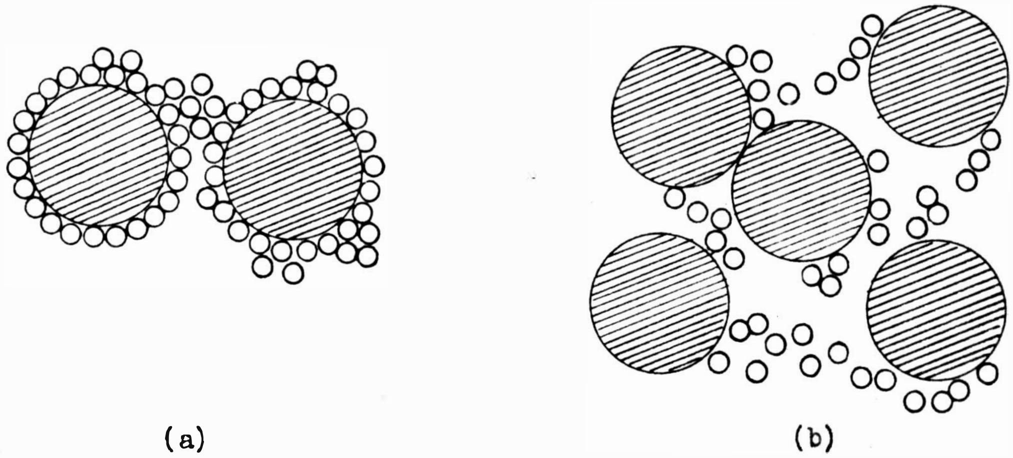
Substitution of Latex: 75 percent

Coating Color No.	101 (Standard)	104	107	110	113	116
	Printing Speed, f.p.m.					
Pick start at	285	0	670	551	276	0
VSP at	285	-	670	551	276	-
SP at	315	-	728	650	-	-
HP at	331	0	778	827	313	0

Code: VSP = Very slight pick SP = Slight pick HP = Heavy pick

Figure 1. Idealized Concept of Latex Bonding

According to Osborne, Satava, and Antlfinger(5)



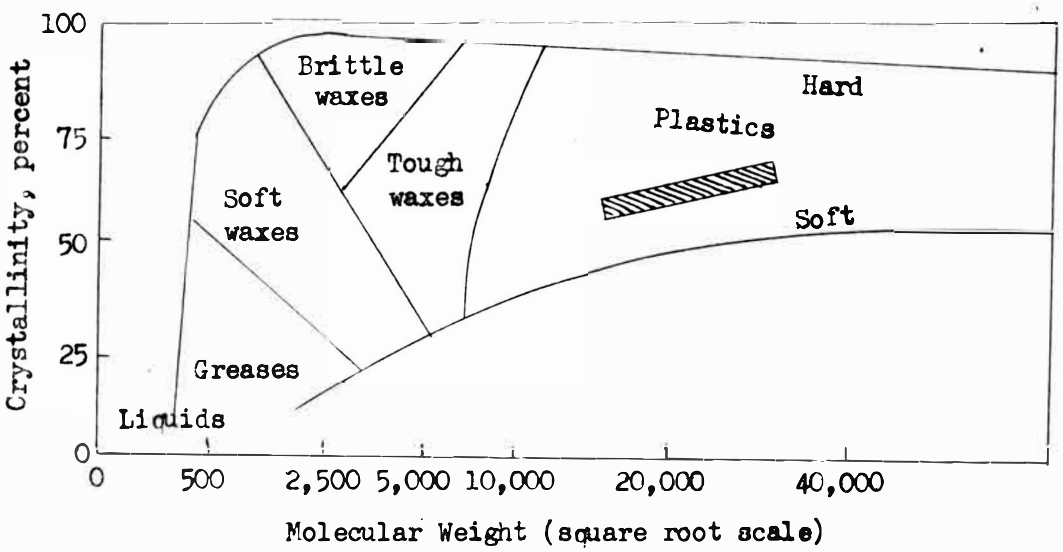
(a)
Complete separation of pigment particles by latex particles

(b)
Imcomplete separation of pigment particles by latex particles

Legend: Light areas are latex binder particles; dark areas are pigment particles.

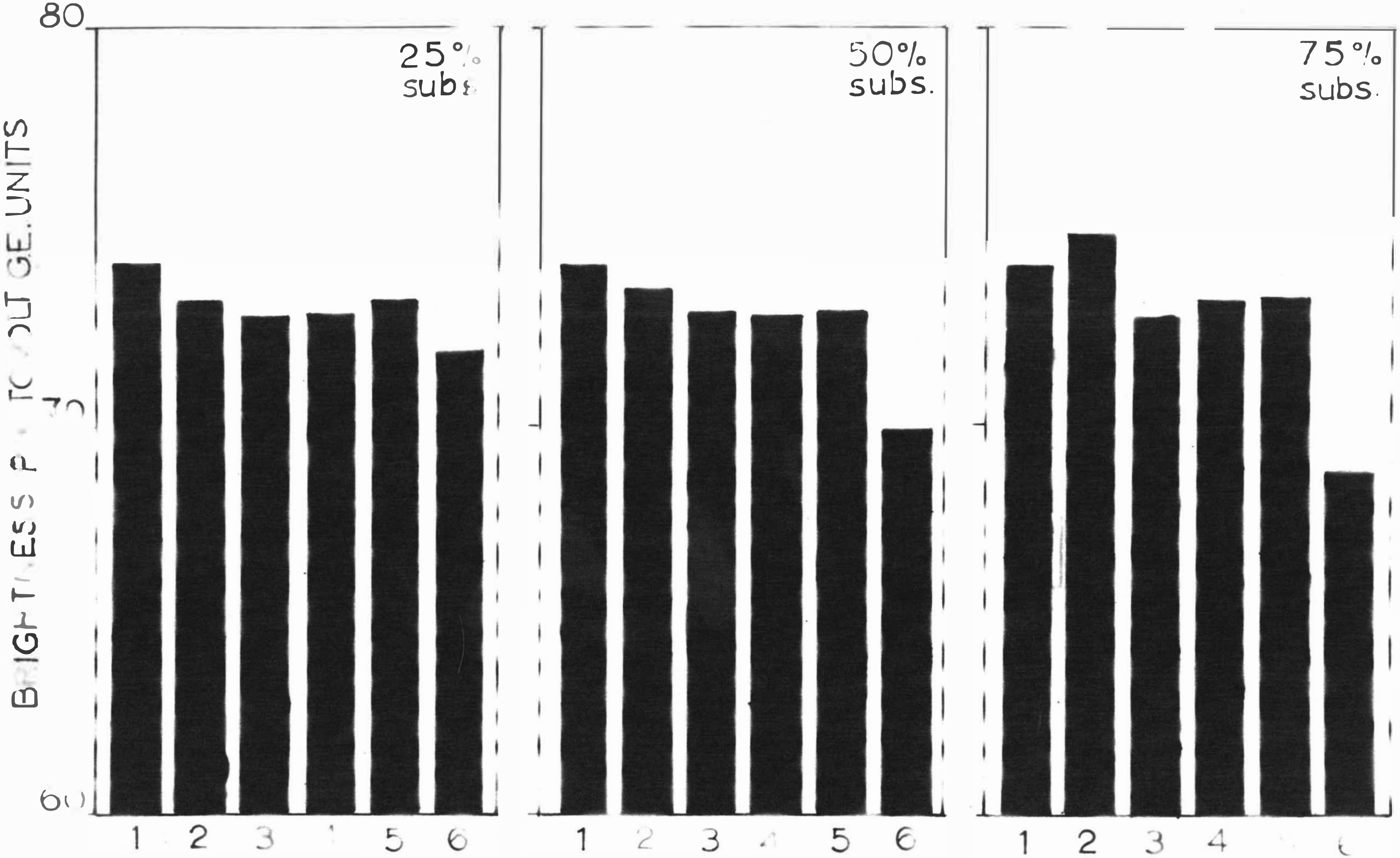
Figure 2. The Interrelation of Chain Length, Crystallinity, and the Nature of the Polymers

According to C. E. Morrell(14)



Crystallinity, Molecular weight, and Properties of Polyethylene

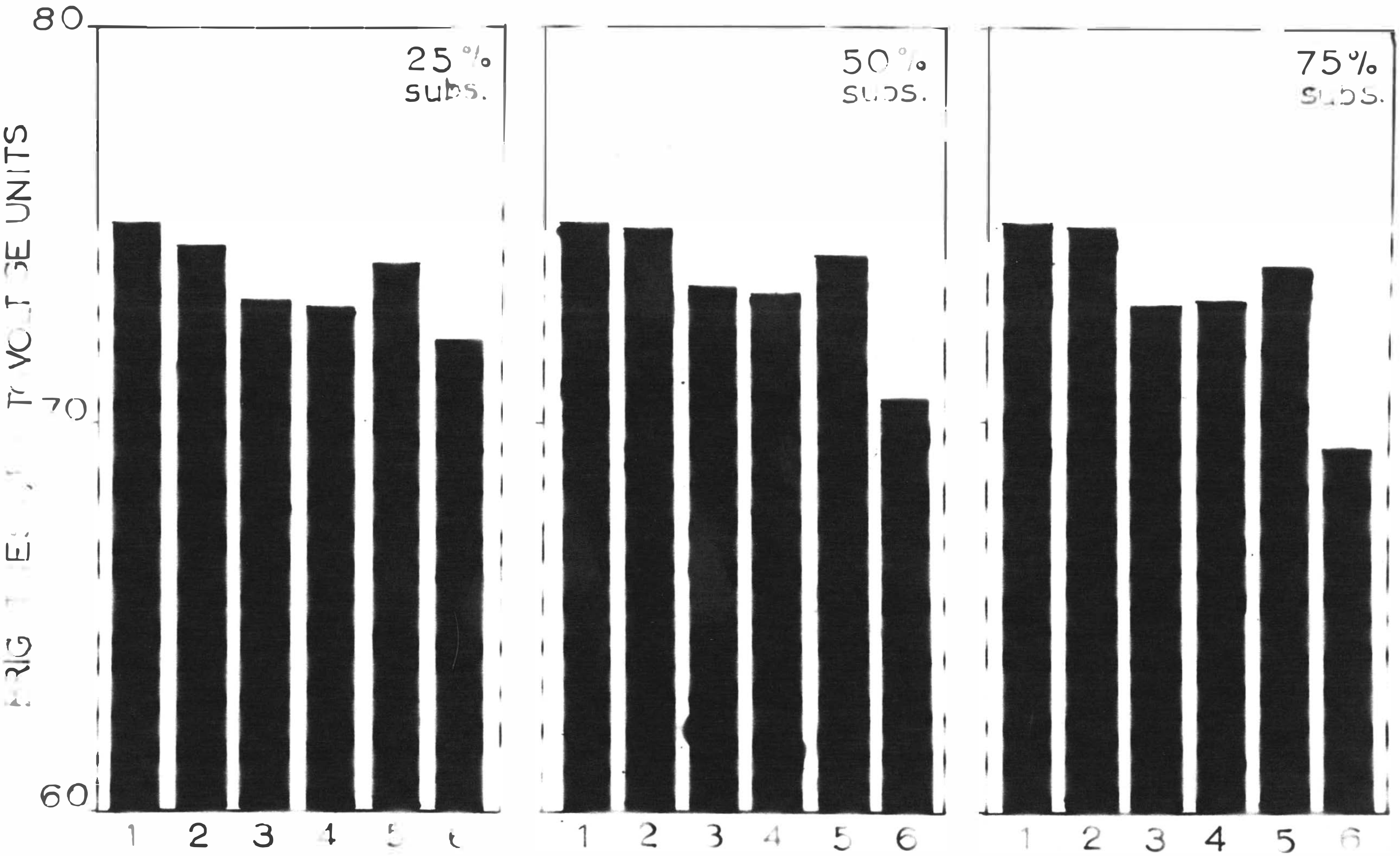
FIGURE 3. BRIGHTNESS OF COATED SHEETS (WOOD BASE PAPER)



CODE: 1 - PLAIN CASEIN (STANDARD) 2 - VINYL ACETATE 3 - ACRYLONITRILE BUTADIENE

4 - ACRYLATES 5 - POLYSTYRENE BUTADIENE 6 - POLYETHYLENE

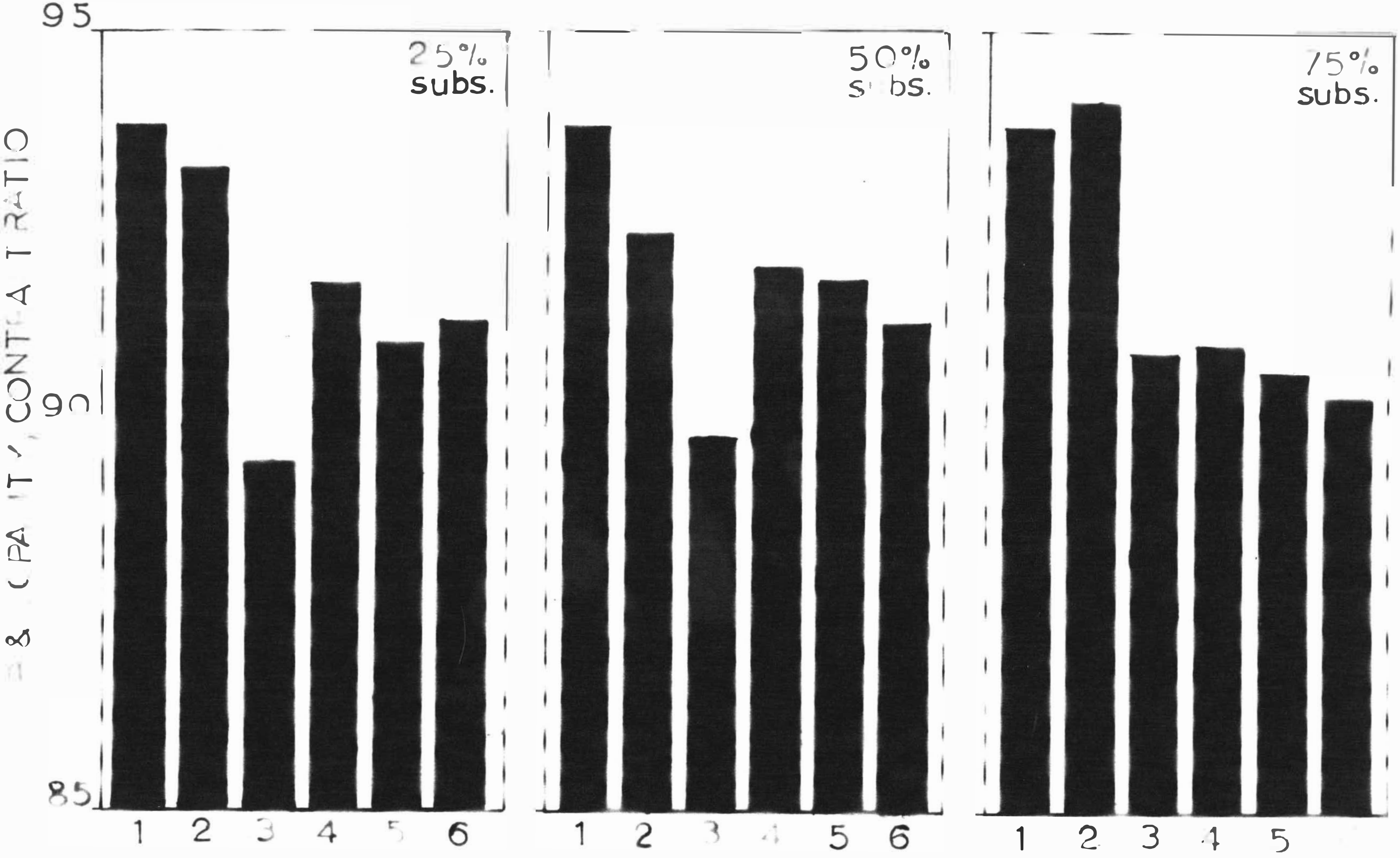
FIGURE 4. BRIGHTNESS OF COATED SHEETS (BAMBOO BASE PAPER)



CODE

1 - PLAIN A[illegible]N (STANDARD)
2 - VINYL ACETATE
3 - ACRYLONITRILE BUTADIENE
4 - ACRYLATES
5 - POLYSTYRENE BUTADIENE
6 - POLYETHYLENE

FIGURE 5. OPACITY OF COATED SHEETS (WOOD BASE PAPER)



CODE:

1 - PLAIN CASEIN (STANDARD)
2 - VINYL ACETATE
3 - ACRYLONITRILE BUTADIENE
4 - ACRYLATES
5 - POLYSTYRENE BUTADIENE
6 - POLYETHYLENE

FIGURE 6. OPACITY OF COATED SHEETS (BAMBOO BASE PAPER)

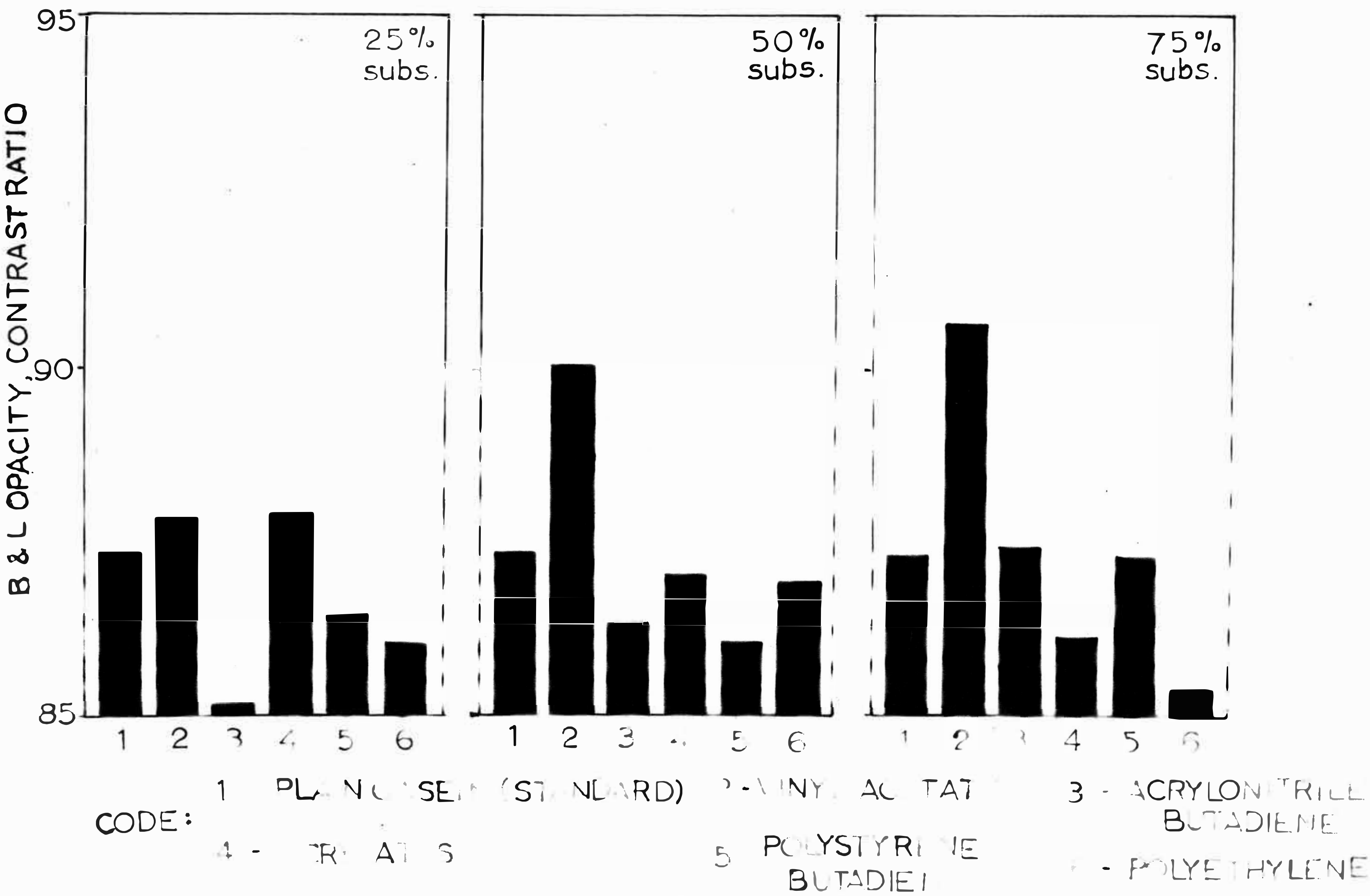
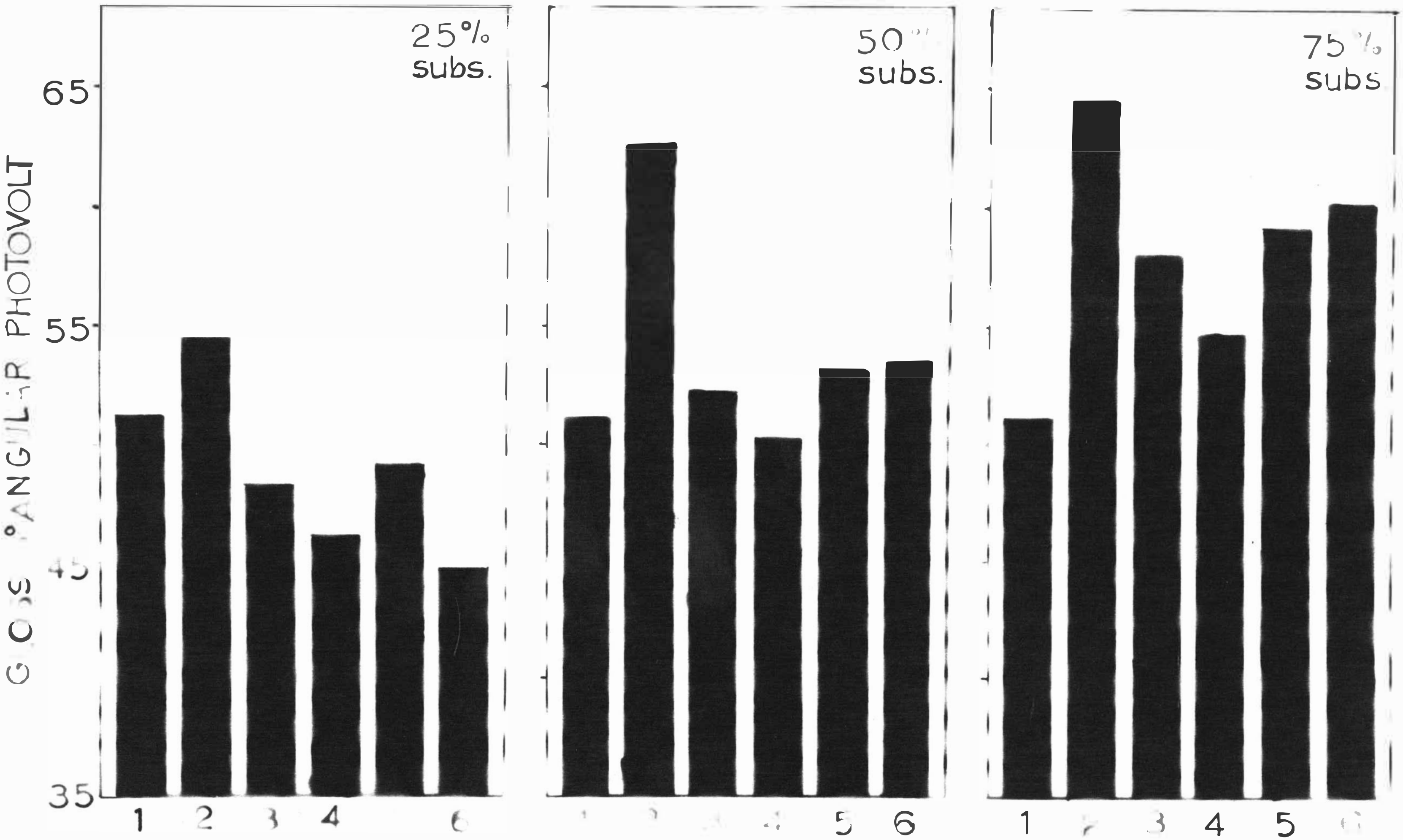


FIGURE 7. GLOSS OF COATED SHEETS (WOOD BASE PAPER)



CODE

1 PL IN AS N (TA DA) -V YL CETATE

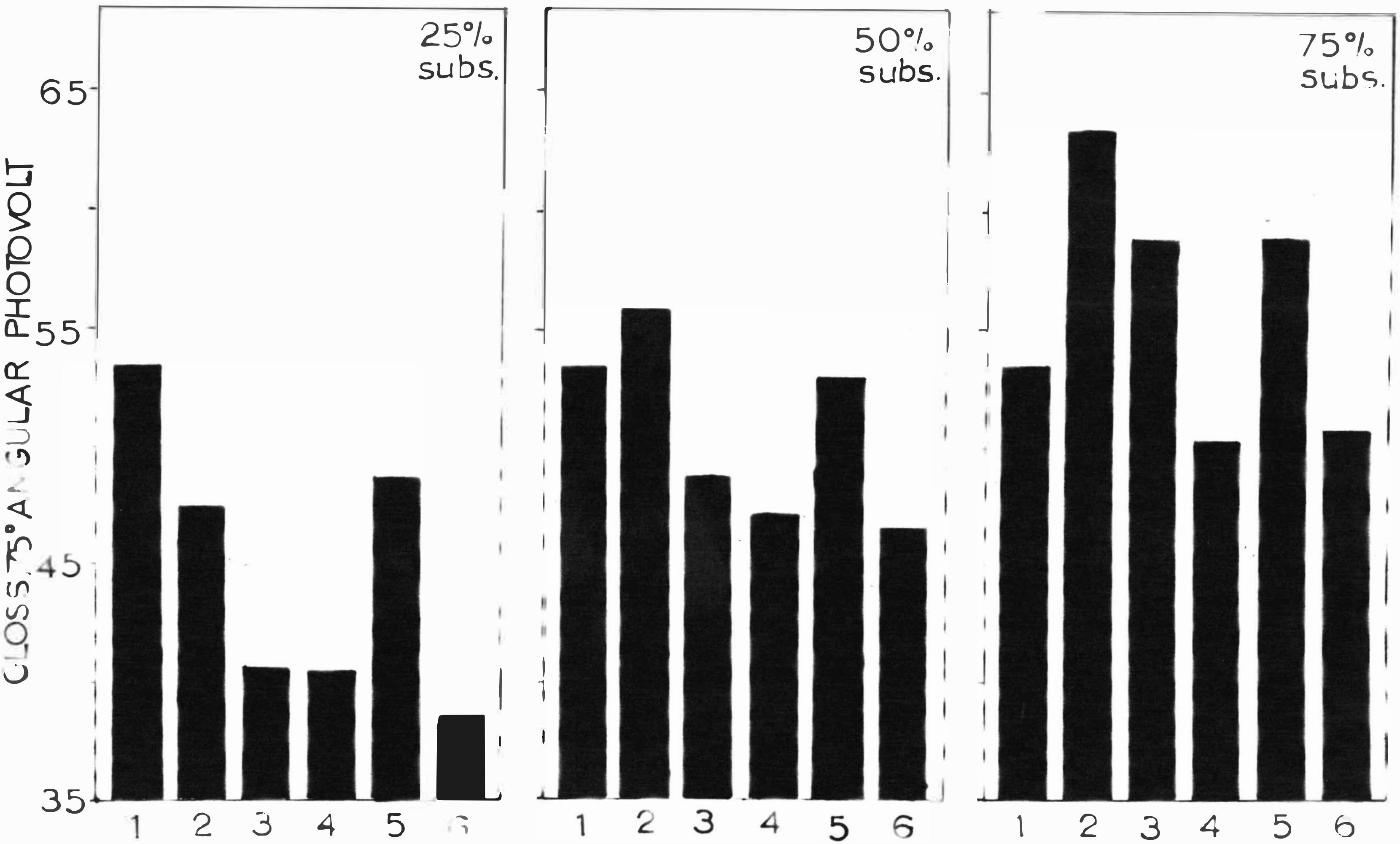
3 - ACRYL NITRILE BUTADIENE

4 - CR LA S

5 PO STY ENE BUTADIENE

6 - POLYETHYLENE

FIGURE 8. GLOSS OF COATED SHEETS (BAMBOO BASE PAPER)



CODE: 1 - ALKALI CASEIN (STANDARD) 2 - VINYL ACETATE 3 - ACRYLONITRILE BUTADIENE
4 - ACRYLATE 5 - POLYSTYRENE BUTADIENE 6 - POLYETHYLENE

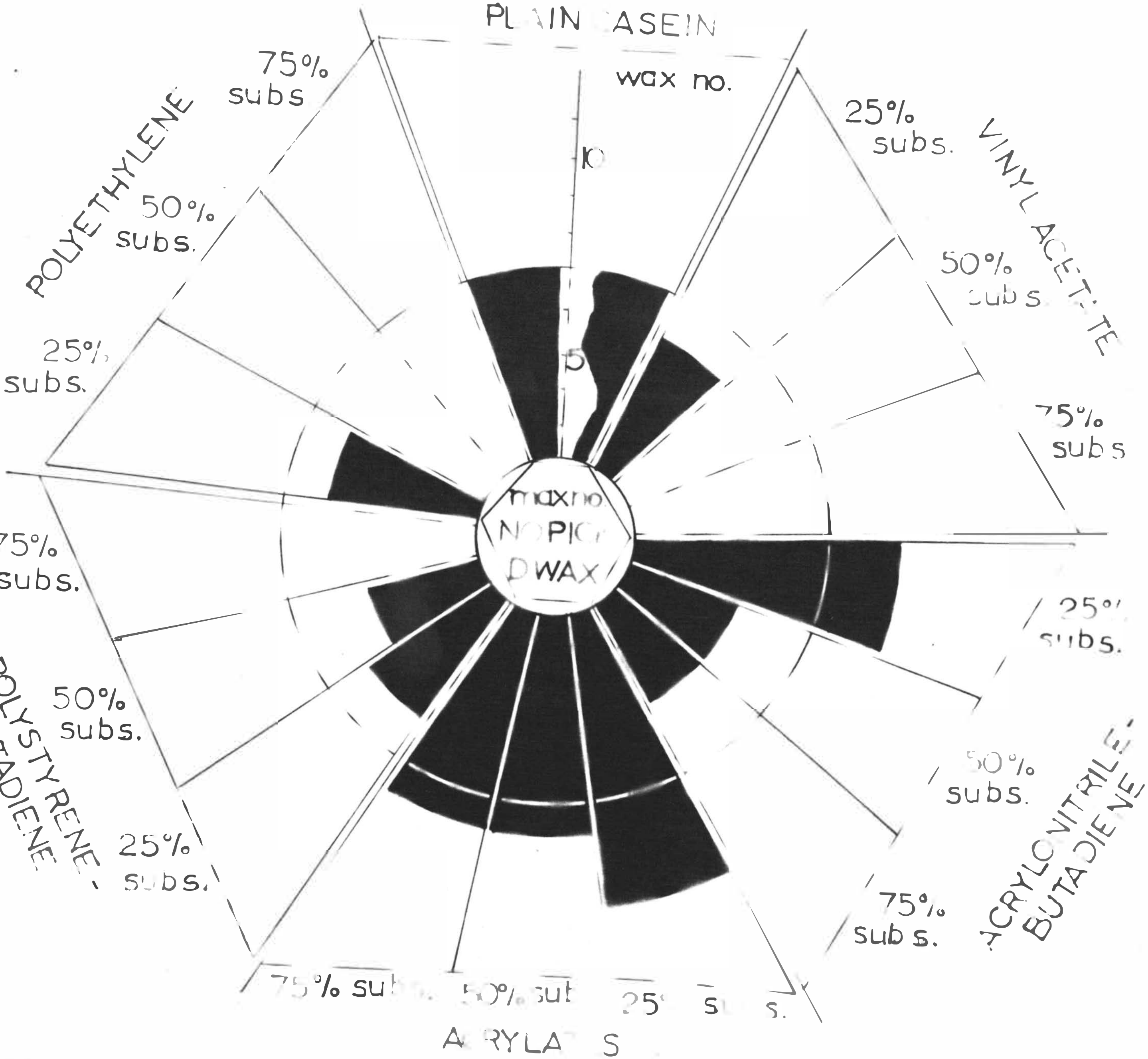


FIGURE 9. DENNISON WAX MAXIMUM PASS NUMBER (WOOD BASE PAPER)

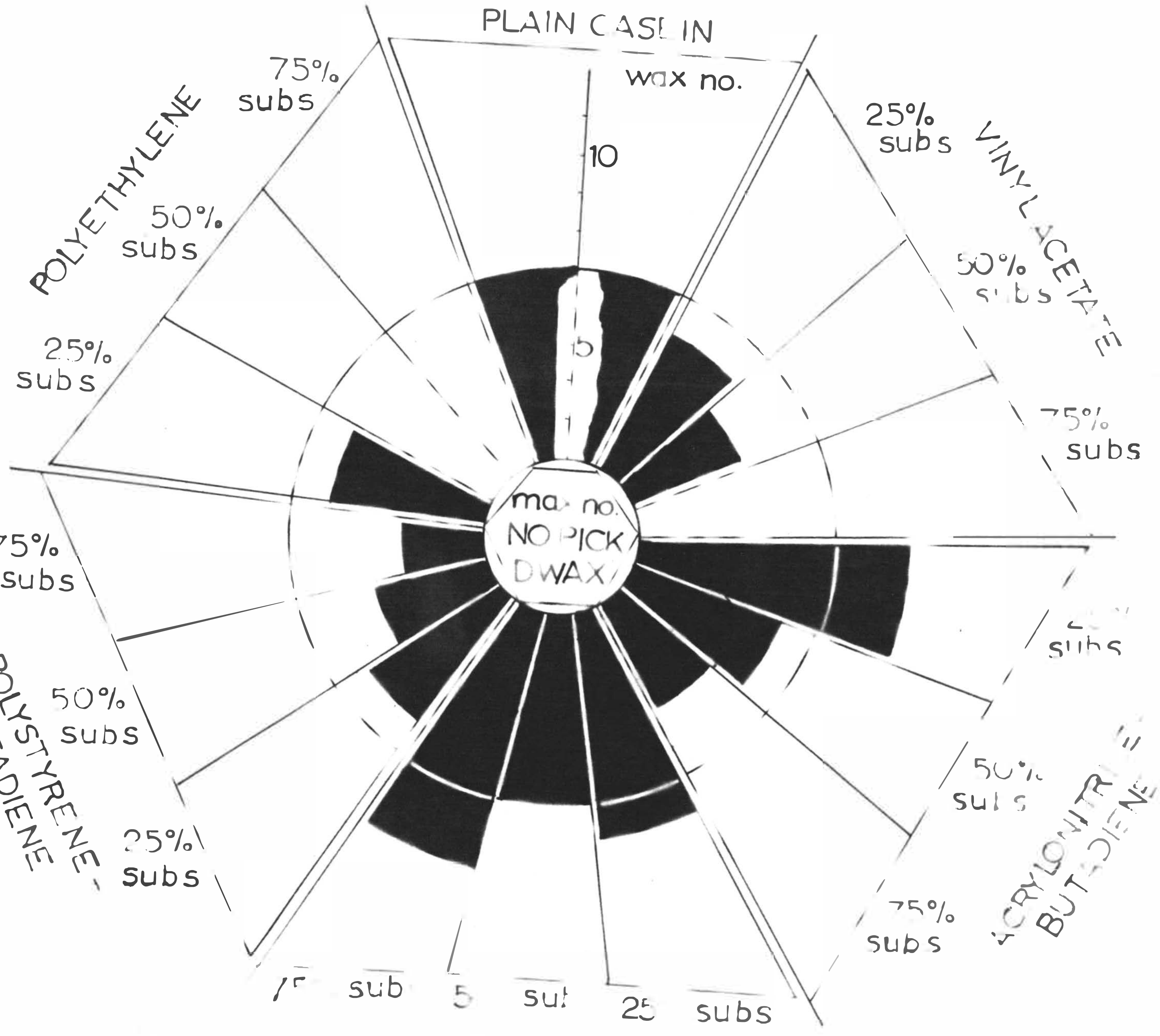


FIGURE 10. DENNISON WAX MAXIMUM ... NUMBER (BAMBOO BASE PAPER)

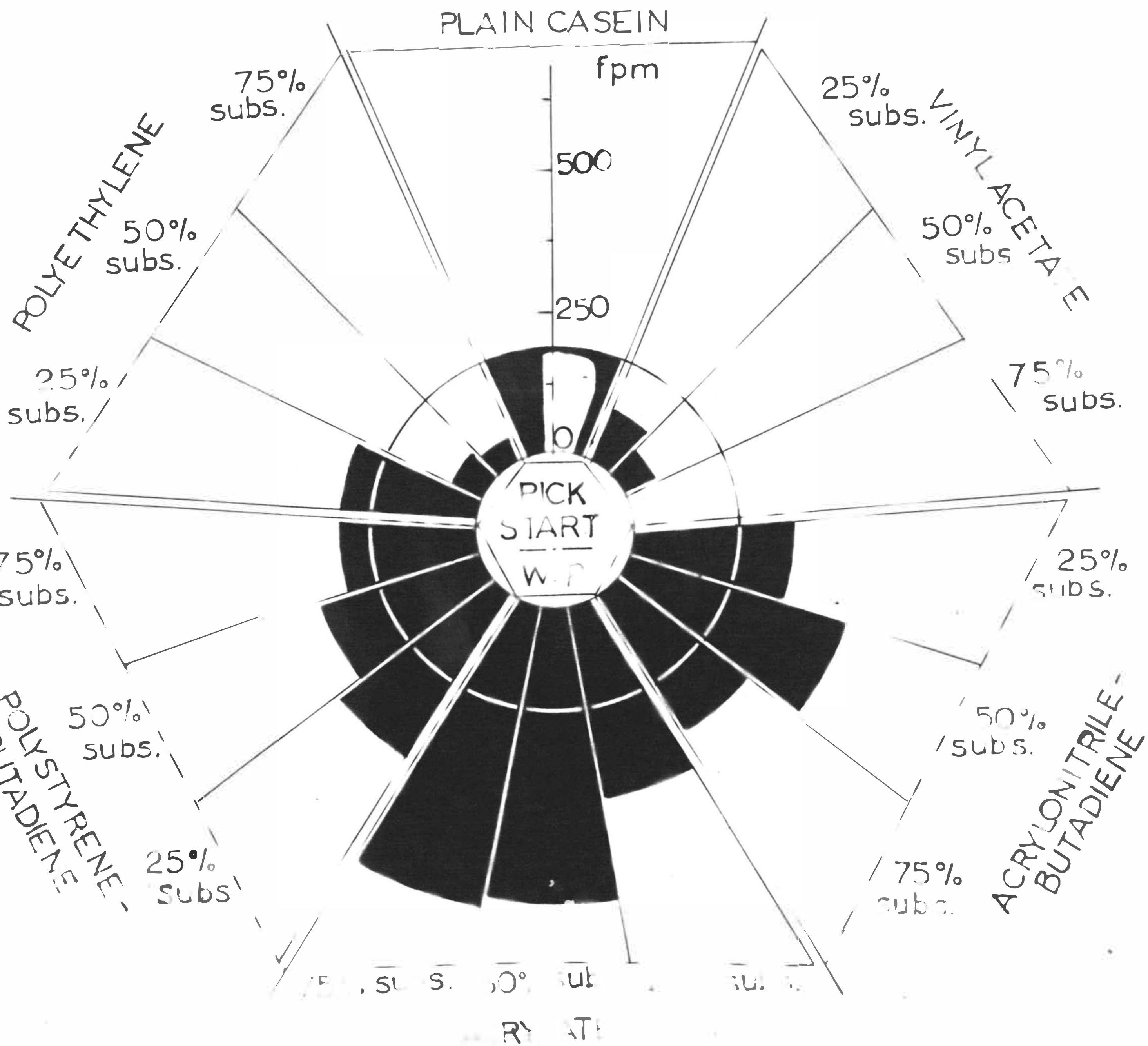


FIGURE 11 PICK START by WAL RC PIC T STE R (WOOD BASE PAPER)

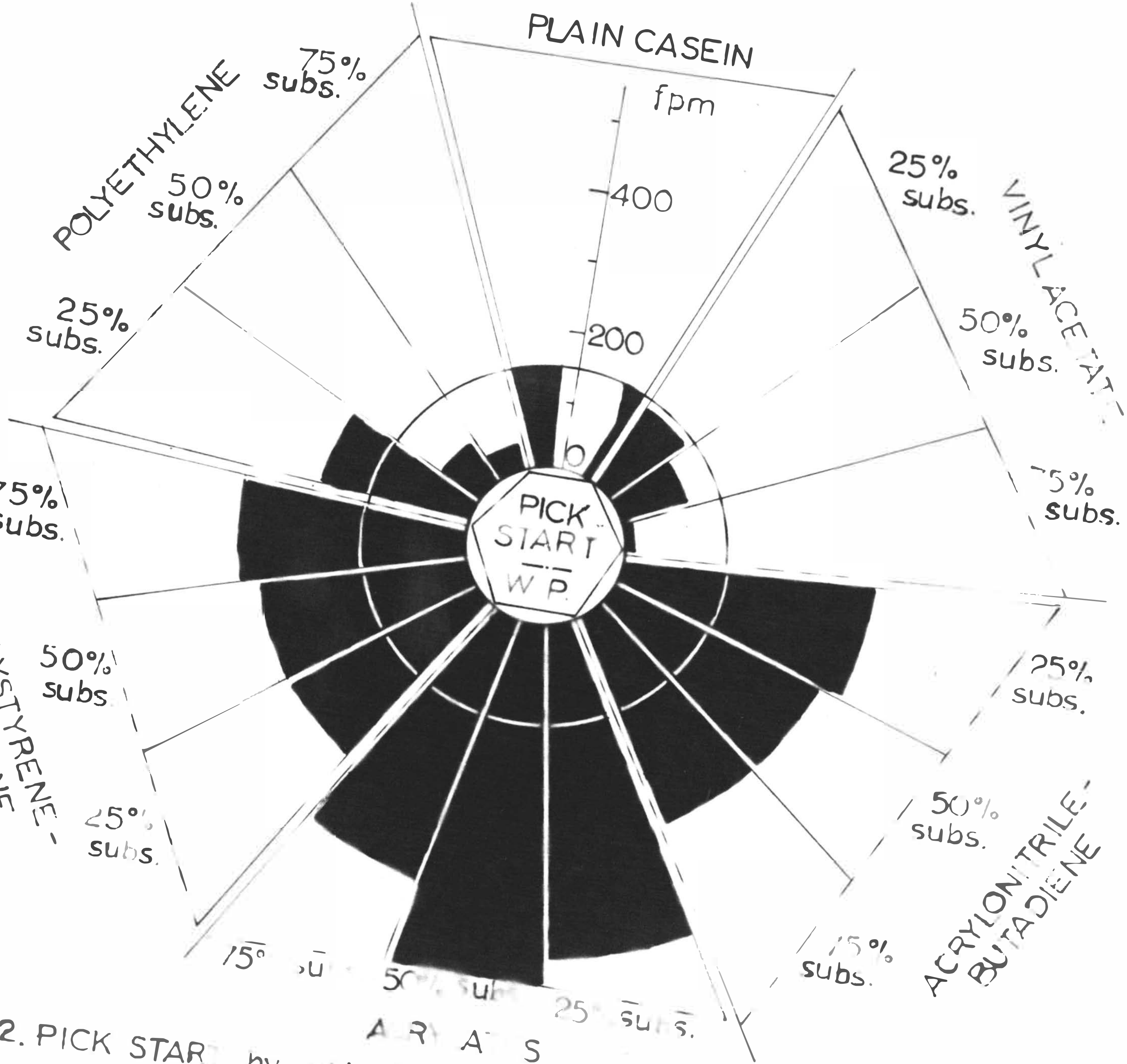


FIGURE 12. PICK START by

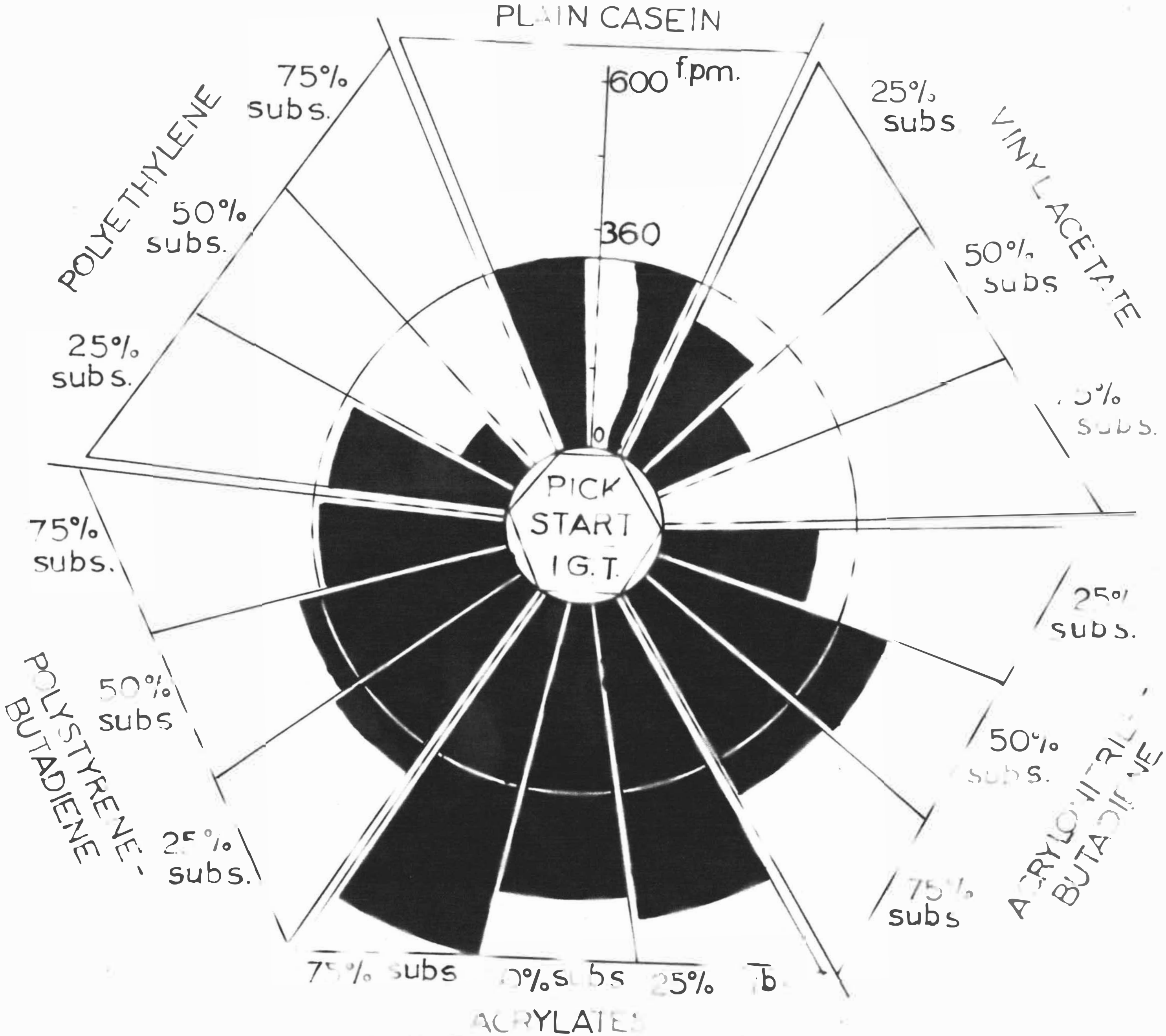


FIGURE 13. PICK START by I. G. T. TESTER (WOOD BASE PAPER)

FIGURE 14 PICK START by I. G. T. TESTER (BAMBOO BASE PAPER)