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THE RELATIONSHIP BETWEEN DEGREE
OF CLAY DISPERSION AND THE
OPTICAL AND PORE PROPERTIES
OF STARCH - CLAY COATINGS

by

Chinu S. Dalal

A Thesis
Submitted to the
Faculty of The Graduate College
in Partial Fulfillment
of the
Degree of Master of Science

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Chinu S. Dalal

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INTRODUCTION

Past coating studies have been carried out to gain understanding of the interrelationship between coating structure and coating performance. These studies have emphasized the importance of the final coating properties such as smoothness, gloss, opacity, pick strength, ink receptivity, and printability. It is evident that more fundamental information is required in order to gain a better understanding of the complete process involved in the coating of paper.

Many of the above common properties are related to the physical structure of the pigment coatings. This structure may be described in terms of the various physical characteristics such as density, surface area, pore volume, pore size distribution, and the alignment of the pigment particles relative to one another. Techniques are readily available for measuring physical and chemical properties of the materials used in preparing coatings. However, there is a major problem in measuring the structure of the coating itself that has the observed properties.

It is the intent of this paper to demonstrate a relationship between the measurable properties of pigment dispersion in the aqueous phase, and dried coating film properties which are believed to be dependent on the packing characteristics and therefore ultimately on the degree of dispersion in the aqueous phase.

HISTORICAL BACKGROUND OF THE PROBLEM

Effect of Particle Packing on Coating Structure

Considerable interest has recently been focused on studying the packing characteristics of pigments in an effort to understand the coating structure and its relationship to the properties of pigmented-adhesive films on paper. The term "particle packing" refers to the manner in which a particle arranges itself in relation to another particle. It pertains to the proximity of one particle to another, both from the standpoint of distance and geometric configuration. Packing or stacking can be orderly, though generally it is a random arrangement of particles. Packing is usually expressed as tight or loose depending upon the closeness of approach of the pigment particles. The term "particle packing" seems simple enough, however the phenomena it describes is extremely complex. There are a number of theories offered to explain particle orientation and arrangement, but, unfortunately, the evidence to support the theories is quite limited in some cases and completely lacking in others.

The particle packing tendencies can be determined by various methods. Hagemeyer (1) has reported four different methods - packed volume of dry pigment blends, centrifuged volume of aqueous dispersed blends, visual observation of large model particles, and packed volume of large model particles. It should be noted that these represent different approaches to the study of particle packing. First, packing

was studied for dry powders with air as the suspending medium. Second, packing was determined by working with aqueous dispersions of the different pigments. Third, packing was determined for plastic replicas of the different material. Hagemeyer (1) observed that the dry mixtures, water dispersions, and plastic models had different packing tendencies.

It has been assumed that the two primary factors which govern the particle packing tendencies of paper coating pigments are particle size and particle shape. Hagemeyer (1, 2) showed with water dispersion in the absence of an adhesive that the packing characteristics of pigments were influenced by the size and shape of the pigment. Cobb (3) concluded that the amount of a particular adhesive required for adequate coating film strength was governed by the percentage of inter-pigment voids which were filled with the adhesive material. Willets and Marchetti (4) attempted to explain various coating properties, such as pick strength and gloss in terms of void volume and the demand for adhesive by pigment.

Hemstock and Bergman (5) observed in the absence of binder that as the amount of tetrasodium pyrophosphate (TSPP) in the suspension was increased until minimum Brookfield viscosity was attained, the percentage of water in the centrifuged sediment and the porosity of the dried film decreased from about 60% to about 40% by volume. These changes resulted in dried films having a large increase in 75° gloss, and substantial reductions in film scattering coefficient and mean hydraulic radius of pores. At optimum deflocculant levels, primary and delaminated clays packed more poorly and in addition produced

dried films of lower gloss and higher scattering coefficient than did the secondary coating clays. These differences did not appear to correlate with average particle size or particle size distribution of the various clays but an excellent correlation was obtained between particle packing in the centrifuged sediment and in the dried coating film.

The above authors (5) have made use of the assumption that coating structure was determined primarily by the packing characteristics of the pigment, independent of the adhesive present. The adhesive, then, in developing the film strength, would only fill in voids. This phenomena is referred to as idealized void filling.

The idealized void filling hypothesis was first tested by Burke (6). The intention of his work was to establish the role of adhesives in the formation of the structure of pigment coatings. Films from three adhesive-pigment systems were formed on a non-porous foil substrate. The results of his study showed that the hypothesis of idealized void filling was not completely valid for any of the adhesive-pigment systems investigated. He found that adhesive actually reduced the pigment film density by increasing the interparticle volume.

Grafton (7) indicated that encapsulation of the pigment particle was the most probable explanation for the expansion of the coating structures when initial increments of adhesive were added to the coating systems. He theorized that the pigment particles were probably encapsulated by a layer of adhesive, the thickness of which was independent of the size of the clay particles. He also found that at

higher levels of adhesive, the coating films were more compact, which was indicated by a decreased film volume and a reduction in pore size and pore volume until all pores were filled.

The process of forming the coating film suggested three mechanisms which could be responsible for changes in film structure as a function of adhesive content and type of adhesive. The first is the encapsulation of the pigment particles by the adhesive. The second shown by La Mer (8, 9) was that polymeric materials can bridge between flocculated pigment particles which could result in an expanded and more porous pigment-polymer structure. The third possible mechanism concerns the effect of changes in surface tension of the coating colors on the packing characteristics of pigment particles. Duff (10) showed that surface tension determined the capillary pressure which developed as the water receded during the drying of a pigment film. Such pressures for water can be quite high and sufficient to pull the clay platelets together and form a compact pigment film. If the surface tension is changed, either by the effect of the binder present or by added surfactants, a lower capillary pressure could result in a less dense pigment packing and an expanded film volume.

Factors Affecting the Scattering Coefficient

Riches and Pascal (11) reported that the light scattering efficiency of a white pigment depends on three factors - the difference between the refractive index of the pigment and binder, the particle size of the pigment, and the distance between the pigment particles

in the coating. Parker (12) also reported that the greater the difference in refractive index between the pigment particles and binder, the better the hiding. Tauth and Jones (13) noted that the relative scattering power of the same coatings when placed on different substrates led to the belief that some factor other than refractive index had an appreciable effect and that this was influenced by the porosity or absorptiveness of the coating structure.

For evaluation of optical performance of coating films Kaliski (14) used the black glass technique. There were several reasons for using black glass plates as model substrate. First of all, it was possible to study coating films which are formed under conditions of minimum interaction between a coating formulation and a substrate, because of a complete lack of surface roughness and absorbency of the glass plates. At the same time, the use of glass plates assured a maximum accuracy of the instrumental determinations of coating film parameters.

Kaliski (14) showed that on the black glass the pore volumes of coatings were as a rule highest with #1 clay, followed by the mechanically delaminated and #2 clay. The maximum relative expansion of the spatial arrangement of the clay particles in coating films containing number two and number one clays was more than twice as high as that obtained with the mechanically delaminated clay. He evaluated coating films and found that the light scattering coefficients of coating films containing binder levels of practical significance were higher with number one clay than with the remaining two clays, which were

nearly equivalent in this respect. The relative loss of light scattering efficiency declined with increasing binder levels in the coatings, and was higher at the wavelength of 557 mm than at 457 mm.

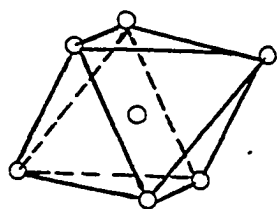
Trader (15) evaluated a wide range of coating clay particle size, ranging from a fine filler grade to a very fine coating grade. He showed that there was a significant loss in scattering power as the clay became finer and also on the coarse side of the #2 clay. Thus his data raised the important question of whether fine particle size clays seriously reduce scattering power of the coating. Hemstock's work (5) does not agree with Trader (15) and he concluded that the differences in optical characteristics of different clays do not appear to correlate with differences in average particle size or particle size distribution although both of the parameters along with particle shape may be responsible. Hemstock and Bergman (5) observed that as the amount of tetra sodium pyrophosphate (TSPP) in the suspension was increased until minimum Brookfield viscosity was attained, the scattering coefficient was decreased to the point of minimum viscosity of the coating then it increased with viscosity.

Clay and Its Structure

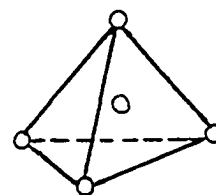
Clay is defined as a disperse system of mineral fragments of hydrated aluminum silicate of which particles smaller than two microns predominate, which is plastic when wet and permanently hard when fired. The term "clay" refers to a physical condition and not a definite chemical composition (16).

Modern concepts of clay mineralogy reveal that clay minerals comprise three main groups, namely, the kaolin group, the montmorillonite group and the illite group. These groups are distinguished not only by differences in chemical composition but more particularly by physical differences as influenced by their crystal structure (16).

The aluminum oxygen octahedron and the silicon oxygen tetrahedron are the basic building units of kaolinite.



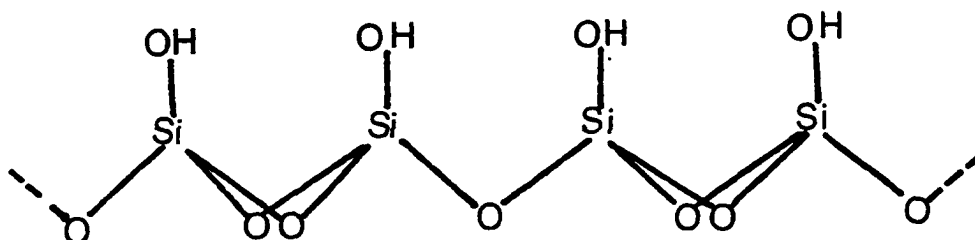
Aluminum - oxygen
octahedron



Silicon - oxygen
tetrahedron

Figure 1

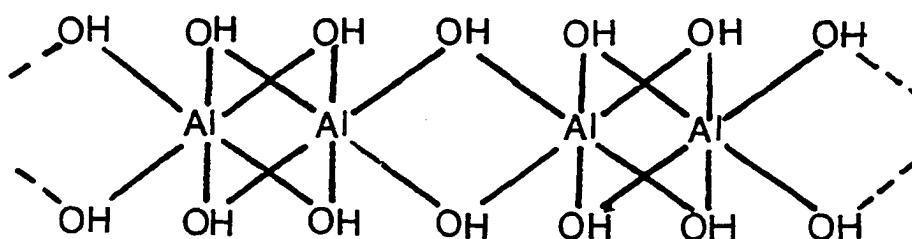
The silicon-oxygen tetrahedron forms a network having the composition $\text{Si}_4\text{O}_6(\text{OH})_4$. A simplified model of this network is shown in Figure 2.



Hydrated Silica Structure

Figure 2

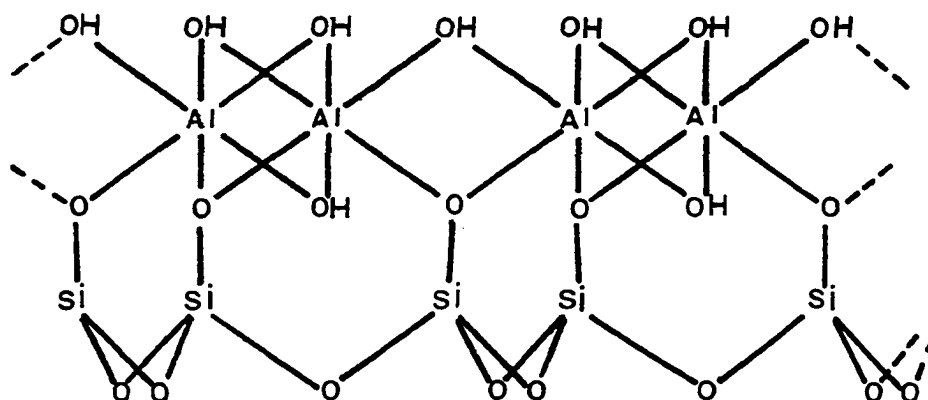
The aluminum-oxygen octahedron, on the other hand, can form a saturated structure consisting only of aluminum and hydroxyl group. This material commonly known as gibbsite, is depicted in simplified fashion in Figure 3.



Gibbsite Structure

Figure 3

These two structural units combine, with the elimination of water, to form kaolinite as shown in Figure 4.



Kaolinite Structure

Figure 4

It is important to note that the net electrical charge of the structure is zero.

Naturally occurring kaolin obviously does not consist of a single silica sheet joined to a gibbsite sheet. The exposed hydroxyl group of the gibbsite sheet offer an excellent opportunity for hydrogen bonding to occur between a gibbsite layer and a silica layer. Since many bonds are possible, these layers may be held together very tightly. Thus kaolinite consist of many alternating layers of silica and gibbsite (17).

For most uses of kaolin it is desirable to have the particle reduced to a fairly small and uniform particle size through wet and dry milling, which reduces the booklets to individual plates and also reduces the size of the plates. The plate shaped particles can be fractured parallel or perpendicular to the silica and aluminum sheet. Fracture in the parallel plane would probably occur where the silica sheet is hydrogen bonded to the octahedral aluminum oxide layer. Fracture in the perpendicular direction would break primary bonds and create some degree of unsaturation on the edges of the resultant particles (18).

There are basically three methods whereby the kaolin particles can acquire a charge. (1) Substitution within the crystalline lattice. (2) Creation of active sites due to unsaturation from broken bonds and (3) Adsorption of ions into the surface in nonactive areas.

Dispersion and Its Aspects

Dispersion is used in two senses, to mean both the process of dispersing a pigment or extender in a liquid medium, and the resulting product. It is necessary also to distinguish between the ease of dispersion and the stability of dispersion. The former is the amount of work required to produce a dispersion of the required degree of fineness. The latter term, the stability of dispersion, is a measure of the freedom from reflocculation and the absence of excessive flocculation of the suspended pigment or extender (19).

Flocculation is defined as an association of particles in the liquid dispersion to form loose clusters from a few to several hundred primary particles. Flocculation is a reversible process, the flocculates being easily broken up by shear, but rapidly reforming. Flocculation may frequently be controlled by the addition of specific deflocculating or flocculating agents to the system (19).

It is useful to consider the overall process of dispersion as consisting of three stages. These three stages are quite distinct in their nature, but in practice they overlap. The principles involved in each stage are fairly well established but because of the overlap it is often not easy to recognize any particular aspect in a practical dispersion system (20). The three stages to be considered are the wetting of the powder, breaking up the clusters to form colloidal particles, and stability.

Wetting of the powder

The wetting of solid surface is dealt with in textbooks of surface chemistry (21, 22) in terms of surface tension, inter-facial tension, and contact angle, and similar considerations apply when the solid is in the form of a powder. A valuable classification of wetting processes was made by Osterhof and Bartell (23), in which three distinct processes were identified:

- (a) spreading wetting, characterized by the spreading coefficient

$$S = \gamma_{SA} - \gamma_{LA} - \gamma_{SL}$$

- (b) adhesional wetting, characterized by the work of adhesion

$$W_A = \gamma_{LA} + \gamma_{SA} - \gamma_{SL}$$

and

- (c) immersional wetting, characterized by the work of immersion

$$W_i = \gamma_{SA} - \gamma_{SL}$$

Where γ is the surface or interfacial tension and the subscripts S, A, and L refer to solid, air, and liquid interfaces; thus γ_{LA} is the interfacial tension at the liquid/air interface.

In the dry state the powder usually contains some aggregates of primary particles and these may be attached to other aggregates and primary particles forming agglomerates. Not only is it necessary for the liquid to wet the external surfaces but it must also displace air from the internal surfaces between the particles in the clusters. Hence this aspect will involve a knowledge of wetting characteristics of the system and some assessment of the dimensions of the internal surfaces.

Breaking up the clusters to form colloidal particles

The most difficult part of the dispersion process to define is that concerned with the breaking down of the aggregates and agglomerates into finer particles after all the available surface has been

wetted. Particles held together by weak forces in the dry agglomerate state would presumably require little energy to disperse, once wetted, and charge and surface tension effects would be important. However, mechanical energy is required to destroy aggregates or break-down single crystals into smaller units, and in practice the relation between grinding efficiency and the adjustable parameters in any particular dispersion process has usually been established empirically.

Stability

Simple dispersions are not generally thermodynamically stable, because of the attraction which exists between the individual particles, and the very large area of interface.

Having wetted the surface and broken down the clusters into fine particles, these are then dispersed throughout the medium. The problem is then to maintain the dispersed state since the particles have a natural tendency to reduce in number with time due to irreversible collisions. An attractive force exists between the particles as they approach, the magnitude of which increases significantly as the distances of approach decreases. The reduction in particle number is here to be termed flocculation, whatever the mechanism involved. To resist flocculation some sort of repulsive force is necessary and this is usually achieved through the particles being charged or containing absorbed layers which protect them, or both.

Principles of Light

When a light ray strikes a plane mirror surface, the angle between the light ray and an imaginary line perpendicular to the surface is called the angle of incidence. The light ray is almost entirely reflected, except for a little absorption of luminous flux which turns into heat. The angle of incidence and the angle of reflection are equal and in the same plane.

When a light ray strikes a plan surface of some transparent material, part is reflected, as from a mirror, part is absorbed and part passes into the transparent material. A light ray passing from air to transparent liquids or solids changes in direction or is said to be refracted as shown in Figure 5.

The angles of incidence, reflection and refraction are in the same plane. The angle of refraction is smaller than the angle of incidence. When light rays pass from air into liquids or solids, light in the shorter wavelengths of the visible spectrum is refracted more than that of longer wavelength, so that the shorter the wavelength, the smaller the angle of refraction.

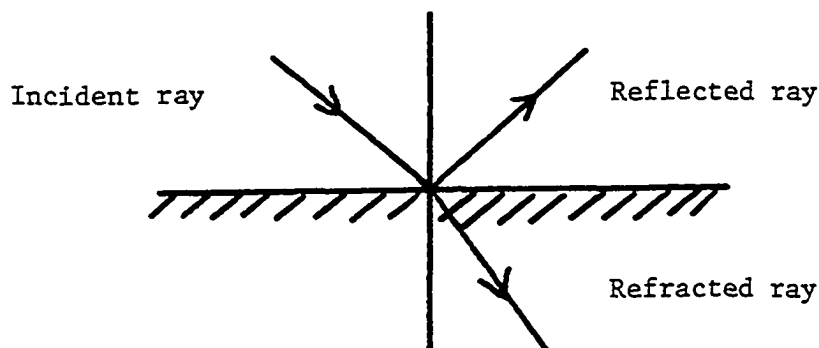


Figure 5

In a scientific analysis of the optics of a coating layer, the importance of the light scattering by pigment particle is recognized in the Kubelka-Munk analysis of the problem (19). The optical properties of a particle dispersed in a medium are characterized by K an absorption coefficient, and S a scattering coefficient.

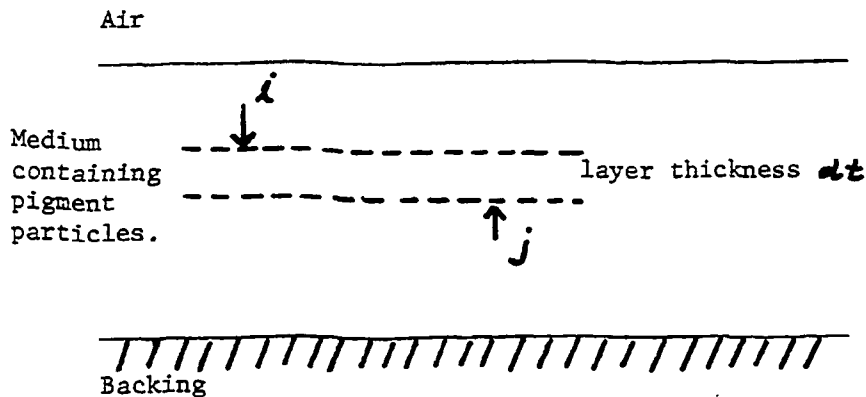


Figure 6 - Absorption and Scattering in a Pigmented Film.

Referring to Figure 6, the decrease in the light flux i entering an elementary layer of thickness dt consist of two parts.

- (1) - $K_i dt$ due to absorption
- (2) - $S_i dt$ due to scattering

However, a light flux j will also enter the layer traveling in the opposite direction and by similar reasoning it will decrease by two amounts.

- (3) - $K_j dt$ due to absorption
- (4) - $S_j dt$ due to scattering

:

The effect of scattering is to reverse the direction of travels of the amounts light flux given by (2) and (4) so that (2) is removed from light flux i , but is added to light flux j . Consequently

$$di = - (K+S)i dt + S_j dt$$

$$dj = - (K+S)j dt + S_i dt$$

A solution to these two different equations was obtained by Kubelka and Munk giving the reflectance of a film R , in terms of its thickness, the reflectance of the backing to the film, the reflectance of a film of such thickness that further increase had no effect on this value (termed R_{∞}) and the scattering and absorption coefficients S and K of the dispersed particles.

These later are related to R_{∞} by what has now become generally known as the 'Kubelka and Munk equation'.

$$\frac{K}{S} = \frac{(1 - R_{\infty})^2}{2 R_{\infty}}$$

Presentation of the Problem

The current effort of the paper coating industry is to achieve lighter coat weight due to increasing demands on coated paper and paperboard performance. Current demands also require other important qualifications; one must maintain printing quality, opacity and gloss-ink hold out (24). It is becoming more difficult to satisfy current demands for these qualities without a knowledge of what coating structures are needed to perform the necessary tasks, and how these coating structures can be obtained.

In the dry condition, coating pigments consist mainly of agglomerates and aggregates formed from individual particles. To prevent flocculation of the particles in an aqueous medium, one uses a dispersing agent. When this aqueous system is applied to a substrate, the transition back to the dry condition may change the degree of dispersion. Kaliski (14) recognized also the possible influence of the substrate and used black glass to eliminate this interaction. Hemstock (5) evaluated packing characteristics of clays in the absence of binder on a glass substrate. Hagemeyer (1) showed how size and shape of the pigment was effecting packing characteristics while still in the aqueous medium. Trader (15) investigated how fine and coarse clays were contributing towards the coating structure again on a black glass substrate.

It has been shown in literature (25, 26) that starch may act as a dispersing agent in aqueous medium. None of the above mentioned

authors have considered the combined effects of starch and TSPP on packing characteristics and, therefore, on coating structure. The main objective of this project was to prepare dried coatings from clay-starch-TSPP dispersions having varying degrees of deflocculation of the clay, and to measure coating pore volume, scattering coefficient, and 75° gloss to determine how the degree of dispersion in liquid coatings affected the structure of dry coatings.

Furthermore, the coatings are to be applied on non-absorptive black glass plates and also on a slightly absorptive resin impregnated paper to obtain an indication of the effect of the absorptiveness of the substrate.

EXPERIMENTAL APPROACH

Introduction

Three types of coatings were prepared; (a) clay with 0.2, 0.4, 0.6, and 0.8% TSPP; (b) clay with 2, 4, 8, and 16 pph starch; (c) clay with starch plus TSPP using combinations of the above amounts. The rheological properties of these coatings were compared using both Hercules rheograms and Brookfield viscosity. The coatings were drawn-down onto both black glass plates and onto smooth, resin impregnated paper substrates with a low rate of absorption. The scattering coefficient, absorption coefficient, pore volume, and gloss of both black glass plate and paper substrates were determined and compared.

Treatment and Preparation of Pigment

The predispersed Ultra White-90 clay was heated in an oven at 450°F. for different lengths of time. The purpose of heating the clay was to convert the pyrophosphate (of predispersed clay) into metaphosphate which does not act as a dispersing agent. A series of clay samples were heated from half an hour to twenty-two hours. The rheograms were obtained for each sample by running the Hercules Hi-Shear Viscometer. The maximum clay-water flocculated system was obtained at five hours. So the clay which was used for this study was heated in an oven for five hours at 450°F. Then it was cooled off. The clay was mixed with water at about 55% solids by a Hamilton Beach mixer.

Starch Preparation

Stayco-M (oxidized) starch was cooked at 20% solids by weight in a steam jacketed beaker with continuous stirring for ten minutes at $170 \pm 5^{\circ}\text{F}$. temperature.

Batch Preparation

After preparing all the required samples, batches were prepared as follows. First of all 0.2% TSPP was dissolved in water based on the dry pigment, prepared clay slurry was added and adjusted to 55% solids. Brookfield viscosities at different rpm and pH were measured of the coating. A rheogram was run on the Hercules Hi-shear viscometer. The same procedure was followed for the three different TSPP levels at 0.4%, 0.6% and 0.8% based on the dry pigment.

In the second part of the work four different levels of starch were used with pigment at 2, 4, 8, and 16 pph respectively. TSPP was not used for this part. The same procedure was followed and all the variables were determined as part one.

In the third part of the work, 0.2% TSPP was dissolved based on dry pigment, prepared clay slurry was added, 2, 4, 8, and 16 pph starch solution were mixed respectively by adjusting the solids of the mixture to 50%. The same procedure was followed for the three TSPP levels at 0.4%, 0.6%, and 0.8% based on dry pigment.

Black Glass Technique (14)

The black glass plates which were custom made, ground and polished to an "optical" flatness were used. The drawdowns were obtained with the use of Bird applicator bars.

The original coating strip which was about 3.5 inch wide and extended from the top to the bottom of the plate, was trimmed with a fresh razor blade (held at a very low angle with respect to the plate to a 3 x 9 inch rectangle with the use of a steel template. Two 0.25 x 3 inch in strips of the coating were separated at the top and bottom of the plate so that a 0.0 - 4.0 mil rolling thickness gage spanning across these strips could be rolled along (over) them, while being supported by the bare glass surface. For both the top and bottom strips the film thickness measurements were carried out twice; one, by rolling the gage from the zero mark toward the 4.0 mil mark and determining the end point of the depression track produced by the gage in the coating surface; a second time, by rolling the gage in the opposite direction and determining the point of origin of the depression track. The above points can best be identified by viewing the depression tracks under a very low angle in a narrow beam of light. The corresponding distances along the strips were measured with an accuracy of 0.1 mm with the aid of precision ruler and magnifier, and converted into film thickness data with the use of a special calculation curve.

The determination of the coating weight was carried out by scrapping off the 3 x 3 inch horizontal coating strip and weighing it with an accuracy of 0.1 mg.

Paper Technique

Drawdowns were made on the plastic vellum paper* by Bird applicator of five different coat weights. All the coatings were air dried. The coat weight was determined on the plastic vellum paper by cutting the coated and uncoated samples in a 2-3/4" x 1-1/2" area. The samples were weighed, the weight of the uncoated sample was subtracted from the coated sample and coat weight in g/m^2 was calculated. The thickness of the coating was determined by taking the difference in caliper reading of the coated and uncoated paper by using an electric micrometer.

Measuring Coating Pore Volume

The pore volume of the coating was determined by subtracting the theoretical coating volume (having no free space) from the actual coating volume. Knowing the coating composition, the specific volume of each ingredient, and the coat weight, permitted the calculation of the theoretical volume.

The relative pore volume (RPV) of the coating was calculated by dividing the pore volume by the theoretical volume.

*Erasa/dure Plastic Vellum (VP16), Technifax, Division of Scott Paper Company, Holyoke, Massachusetts.

Determination of Brightness of Coating Films (R_{05}) (27)

To determine R_{05} , the coating is applied to a translucent paper and the brightness of that coated paper is measured backed by chips of different brightness. This method is an extension of a method suggested by A. T. Luey (27) in which the coating is applied to the paper at a coating weight typical of that at which the coating will be used and reflectance measurements are made on both the coated and uncoated samples. The brightness of the backing materials is varied by placing different standard brightness chips below the samples in the brightness measurements. Thus, for each backing chip, we obtain a value of R_g (uncoated paper and chip) and the corresponding value of R (coated paper and chip). To determine R_{05} , a plot of the data is constructed as shown below.

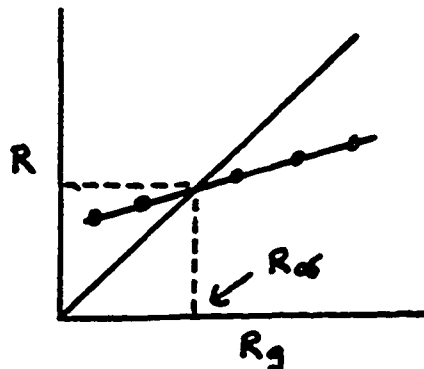


Figure 7

The brightness R of the coated paper was plotted on the vertical co-ordinate; R_g was plotted horizontally. A 45° reference line, defining the locus of all points for which $R = R_g$, passes through the origin. The point of intersection of the R versus R_g plot

with the 45° line indicates that value of R_g for which the addition of the coating has no effect on the brightness of the uncoated paper. This is the R_∞ of the coating.

Determination of S (28)

To determine S, it is necessary to have two additional points (R and R_g). These points are conveniently obtained by using a black chip behind the uncoated and coated papers. Using the data R and R_g for this point and the R_∞ already determined, S is calculated by the following formula derived from the Kubelka and Munk theory.

$$S = \frac{R_\infty}{(1 - R_\infty^2)X} \ln \frac{(R_\infty - R_g)(1 - R_\infty R)}{(R_\infty - R)(1 - R_\infty R_g)}$$

Where

- X = Coat weight, g/m^2
- R_∞ = Brightness of the coating, %
- R_g = Brightness of the uncoated paper backed by the black chip, %
- R = Brightness of the coated paper backed by the black chip, %.

The scattering coefficient of the coating on black glass was determined by the following method: From the values of the reflectance of the coating over a black body, R_o , the scattering power can be computed, and hence the scattering coefficient of the coating from the relationship.

$$R_o = \frac{SW}{SW + 1}$$

Where

R_o = Brightness of the coating over a black glass, %

W = Coat weight, g/m².

PRESENTATION OF RESULTS AND DISCUSSION

Effects of TSPP and Starch on Viscosity

The heat treated predispersed premium clay was deflocculated to varying degrees by the addition of different amounts of tetrasodium pyrophosphate (TSPP). Brookfield viscosity data indicated that the minimum viscosity was obtained by adding about 0.13% TSPP (Figures 8 and 9). This amount is lower than normal (0.3%), probably due to the sodium ion and phosphate remaining in the clay after the heat treatment. The data demonstrates that enough of the original dispersant was decomposed to satisfy the needs of this project.

When only starch was added to the clay, the minimum viscosity was obtained at 8 parts per hundred (pph). Coating viscosity increased with starch contents higher than 8 pph (Figure 10). Thus, showing that starch might also be considered to act as a dispersing agent. Theories to explain the possible mechanisms of starch dispersing pigment have been presented by Kline (25) and Wilhelm (26). Other theories to explain the interaction have been presented by Burke (6) and Grafton (7), but the mechanism of the starch-pigment interaction will not be discussed in this paper. The data does show that the slips prepared do vary in viscosity and the change will be interpreted as being due to a change in the degree of dispersion.

Looking at the Brookfield viscosity data in Figure 11 it is obvious that the presence of starch reduced the sensitivity of the

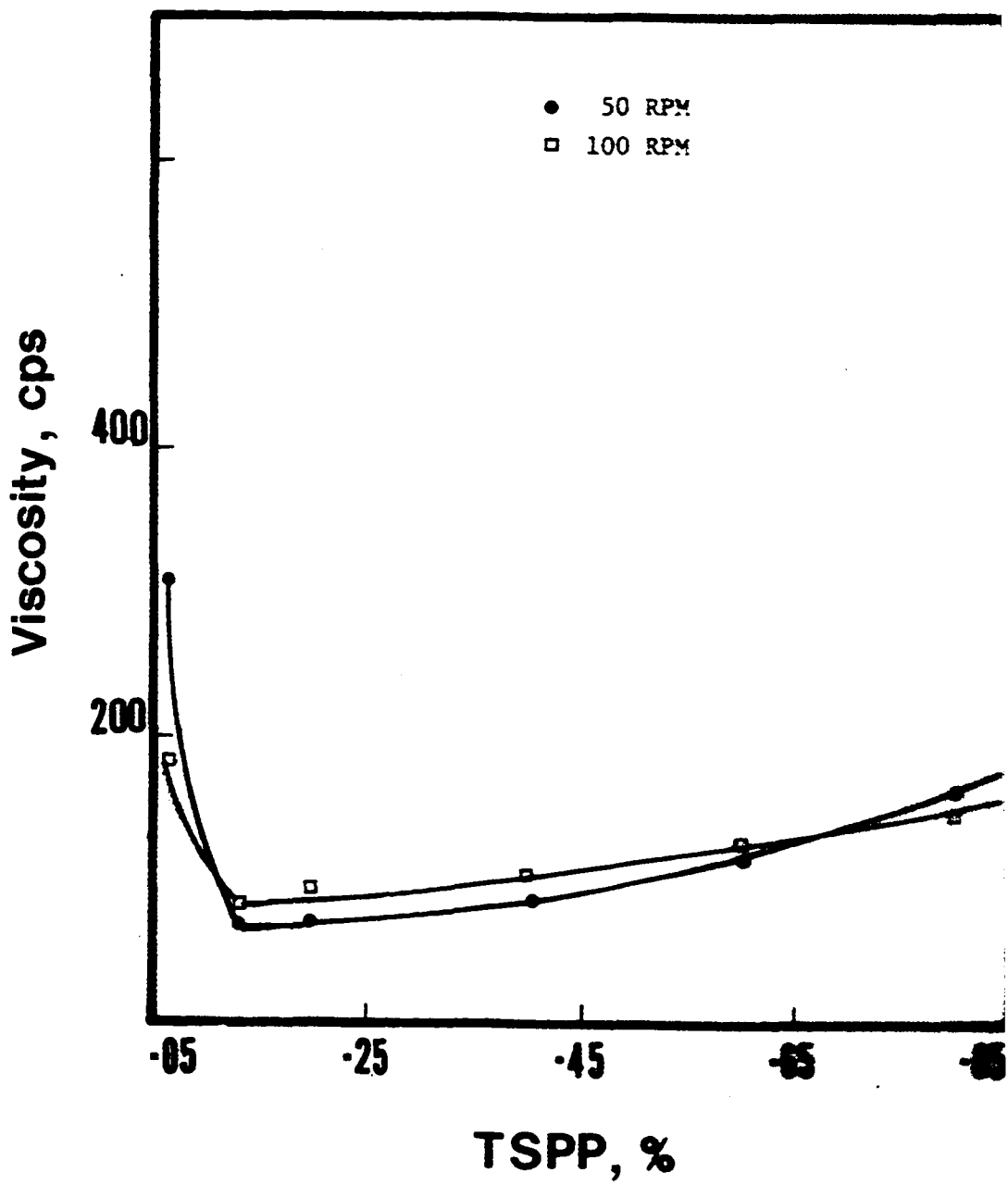


Fig. 9

Effect of TSPP on Brookfield Viscosity of Clay Slip

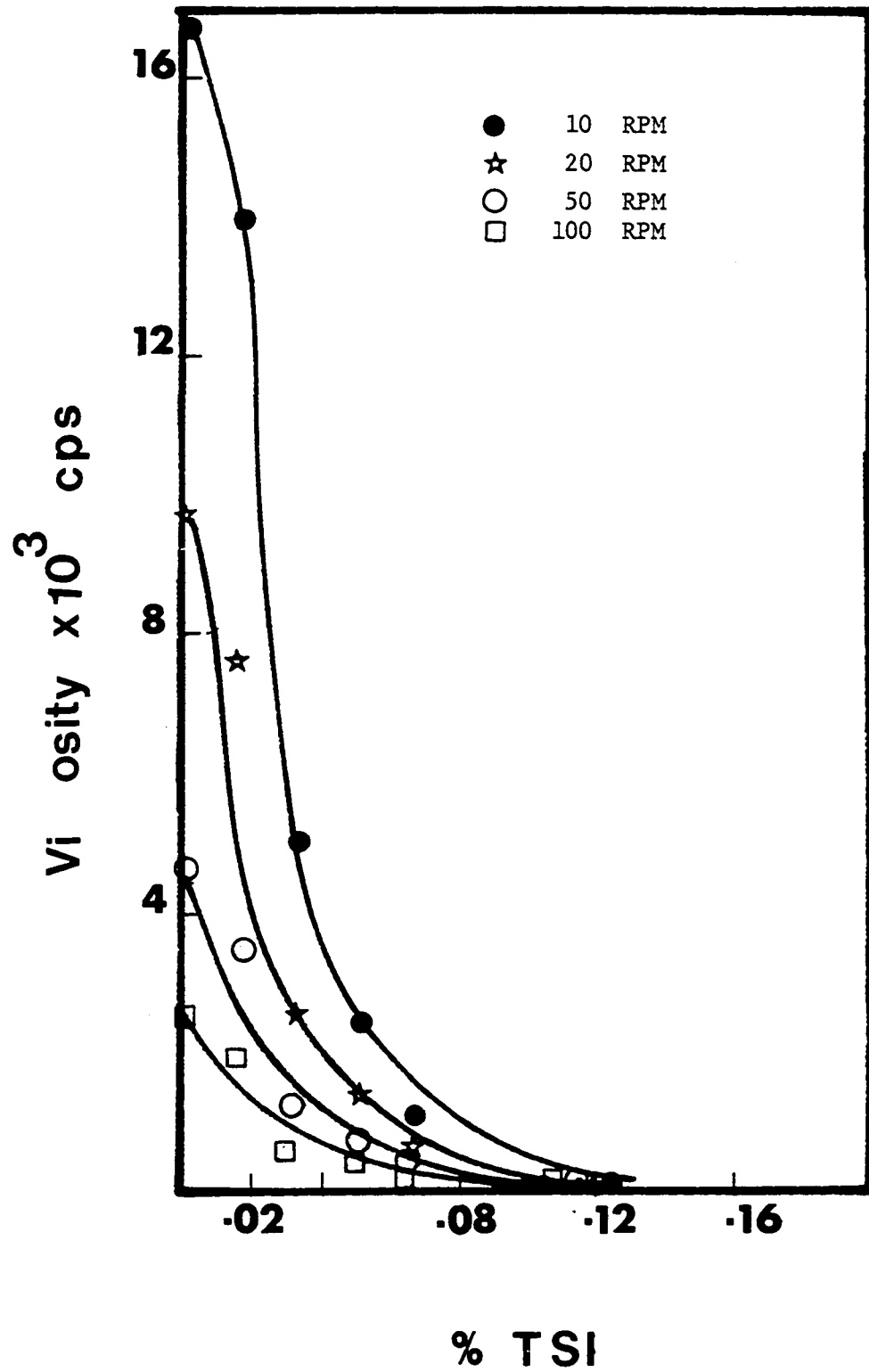


Fig.8

Effect of TSP on Brookfield Viscosity of Clay Slip

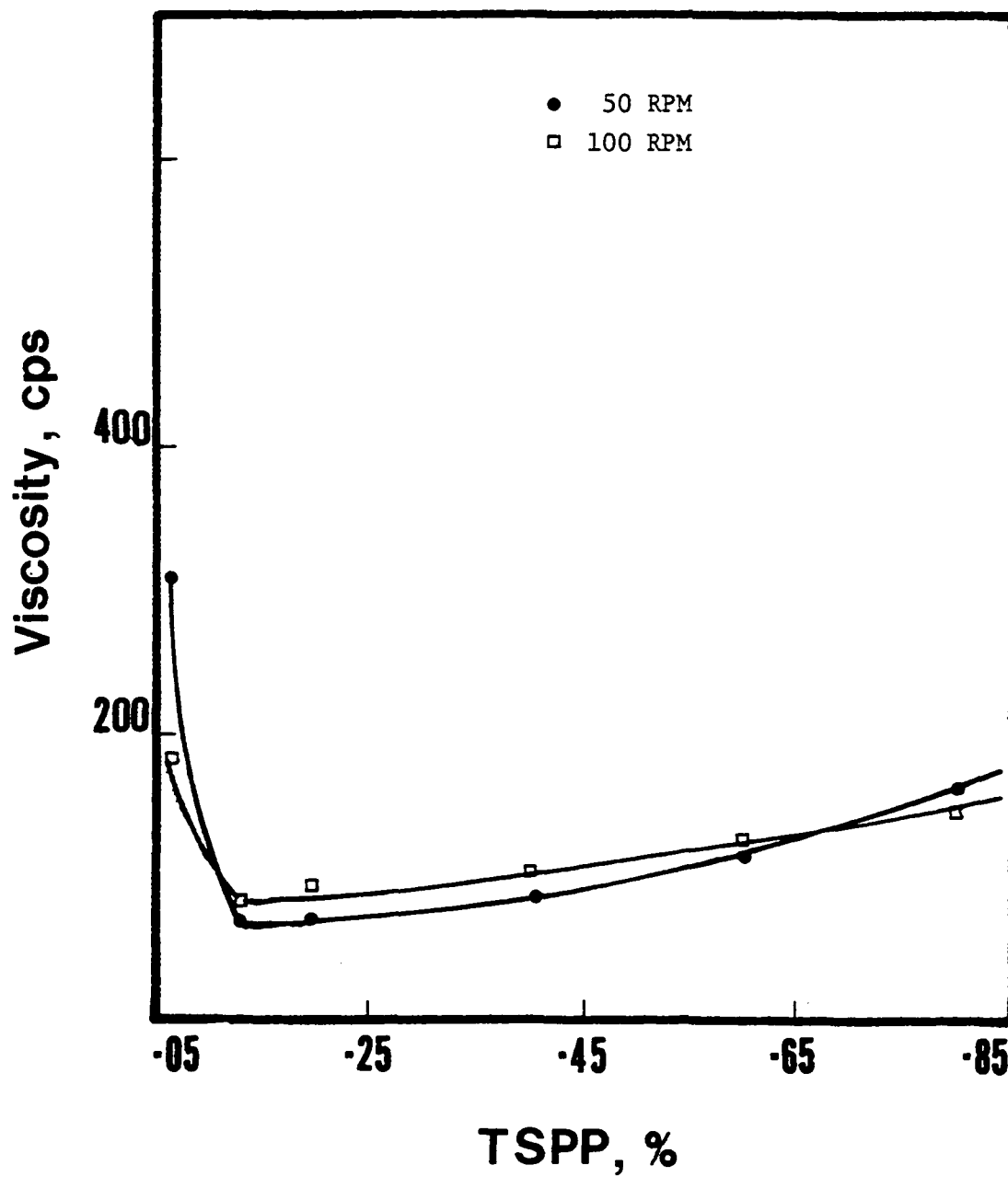


Fig. 9

Effect of TSPP on Brookfield Viscosity of Clay Slip

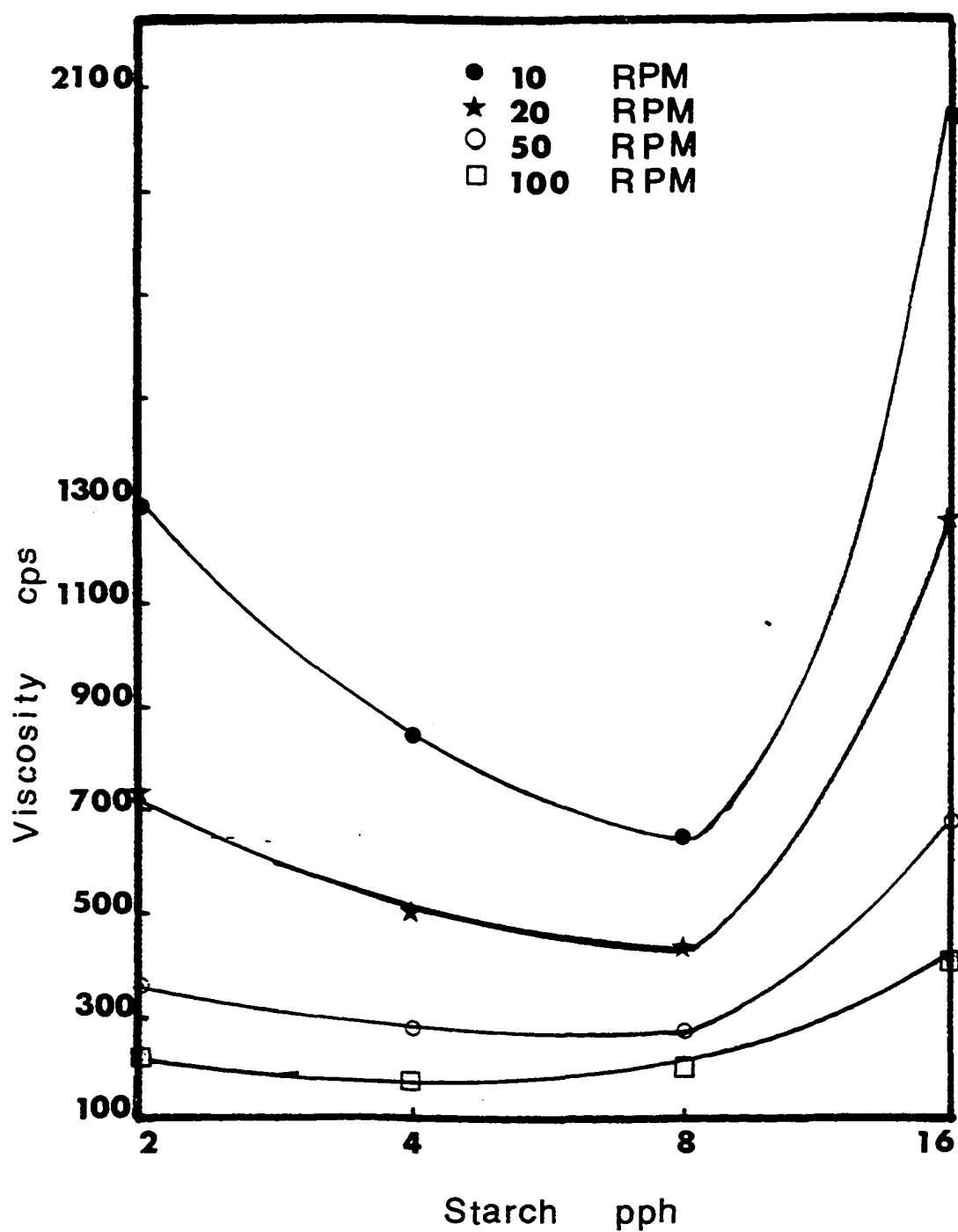


Fig.10

Effect of Starch on Brookfield Viscosity of Clay Slip

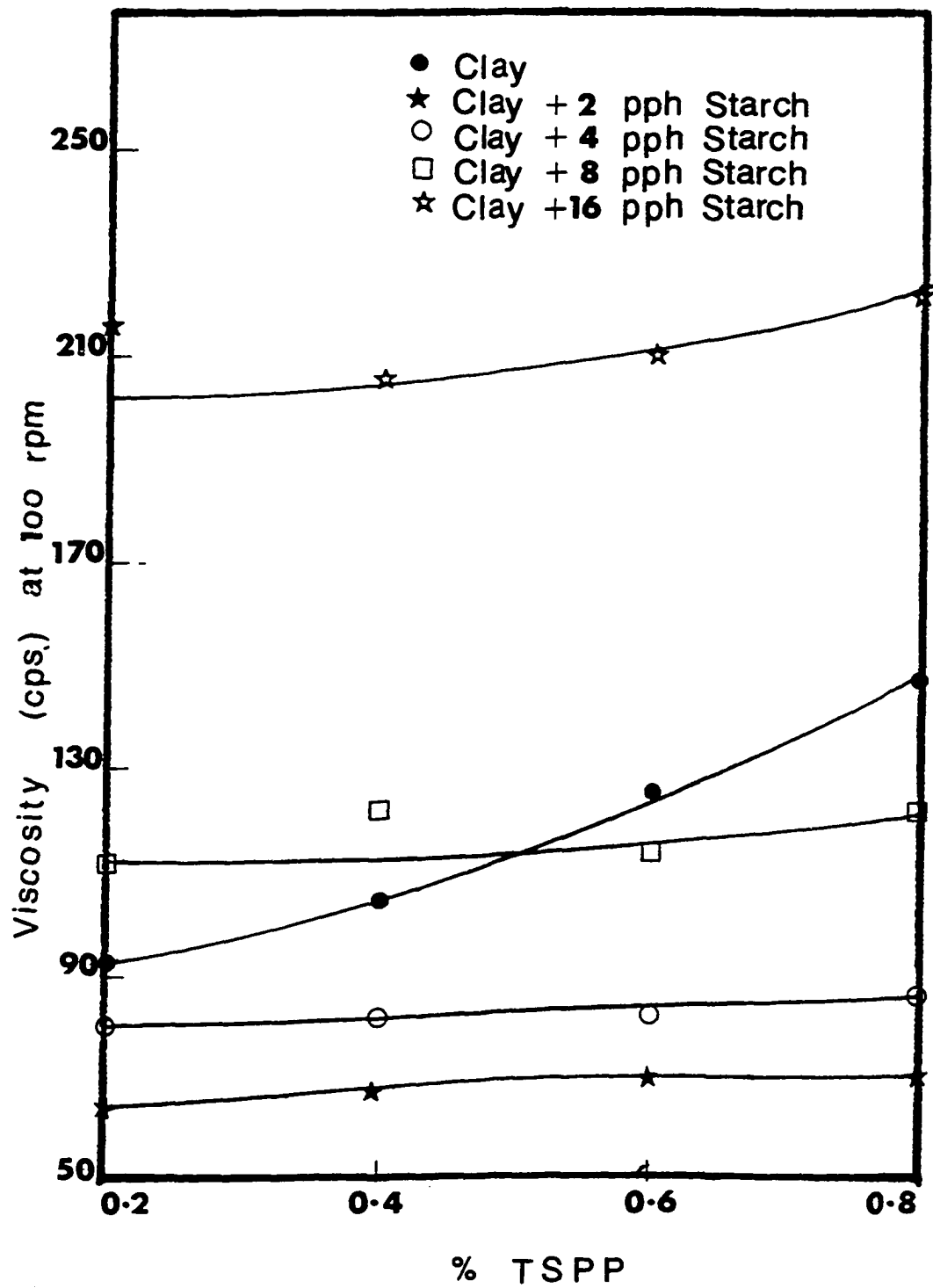


Fig.11

Effect of TSPP on Brookfield Viscosity at 100 RPM

viscosity measurement to the different amounts of TSPP. Particularly with 16 pph starch there was not much difference in the viscosity caused by adding the dispersing agent. These results appeared more significant as far as commercial production was concerned because 16 pph starch does stand in the commercial range of coatings. This data shows that at high levels of starch, the effectiveness of the TSPP was reduced and the system was assumed to be overdispersed and flocculated.

Hercules rheograms were run for all the coating batches and representative curves are shown in Figure 12. The clay slip gave a plastic system but the plasticity was reduced by the addition of starch and/or TSPP. When the different amounts of TSPP were added, pseudoplastic curves resulted indicating that the systems were overdispersed. The increased amounts of starch caused a reduction in the plasticity of the slips and also caused some degree of thixotropy. The disappearance of plasticity at 8 pph starch coincided quite well with the minimum Brookfield viscosity (Figure 10) in that both indicate that the clay was quite well dispersed at this level of addition.

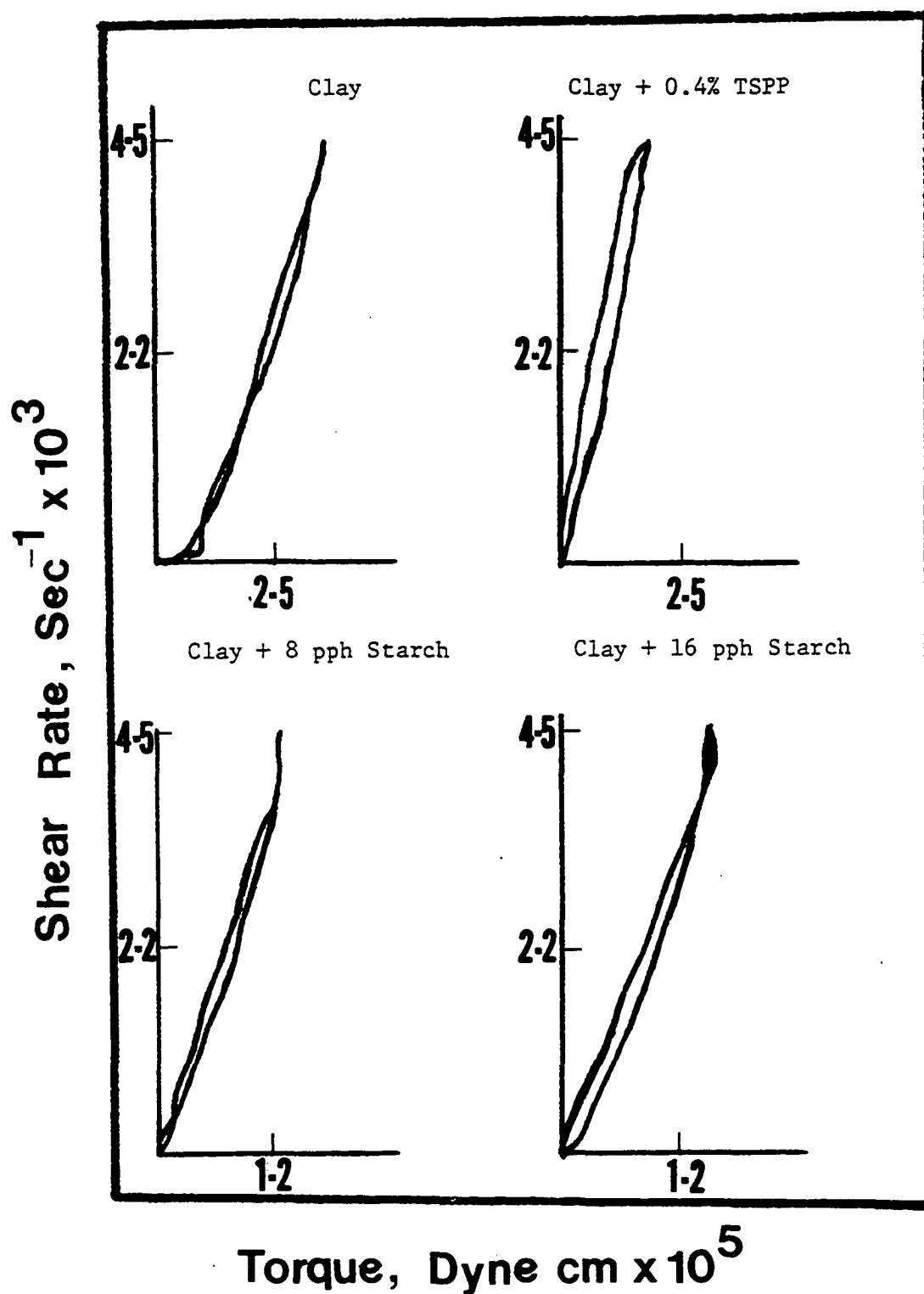


Fig.12

Hercules Hi-Shear Rheograms of Representative Batches

Scattering Coefficient as a Function of the Coat Weight of Both Paper and Black Glass Substrate

The degree of dispersion cannot be discussed until the coat weight influence is covered because of the strong influence of coat weight on scattering coefficient. In the clay-TSPP systems, very smooth curves were obtained (Figure 13) showing that increasing the coat weight greatly decreased the scattering coefficient. When starch was added to the clay-water system, the scattering coefficient was first increased and then decreased (Figure 14). At the low levels of starch, the scattering coefficient peak was the highest and as the starch level was increased, the peak value was lowered and shifted towards higher coat weights. With different combinations of TSPP and starch, the scattering coefficient of the coating was first increased then decreased as the coat weight was increased (Figures 15 - 18).

The capacity of a coating layer to hide the substrate is dependent chiefly on the number and size of pigment particles and on their light scattering and absorbing capabilities. The increase in scattering depends on air-pigment interfaces. Later data will show pore structure increases which correspond to these scattering coefficient increases at low coat weights. The decrease in scattering coefficient could be explained as a surface effect in that there is more scatter at the surface and increased coat weight does not increase surface but dilutes its effect in the total weight of coating.

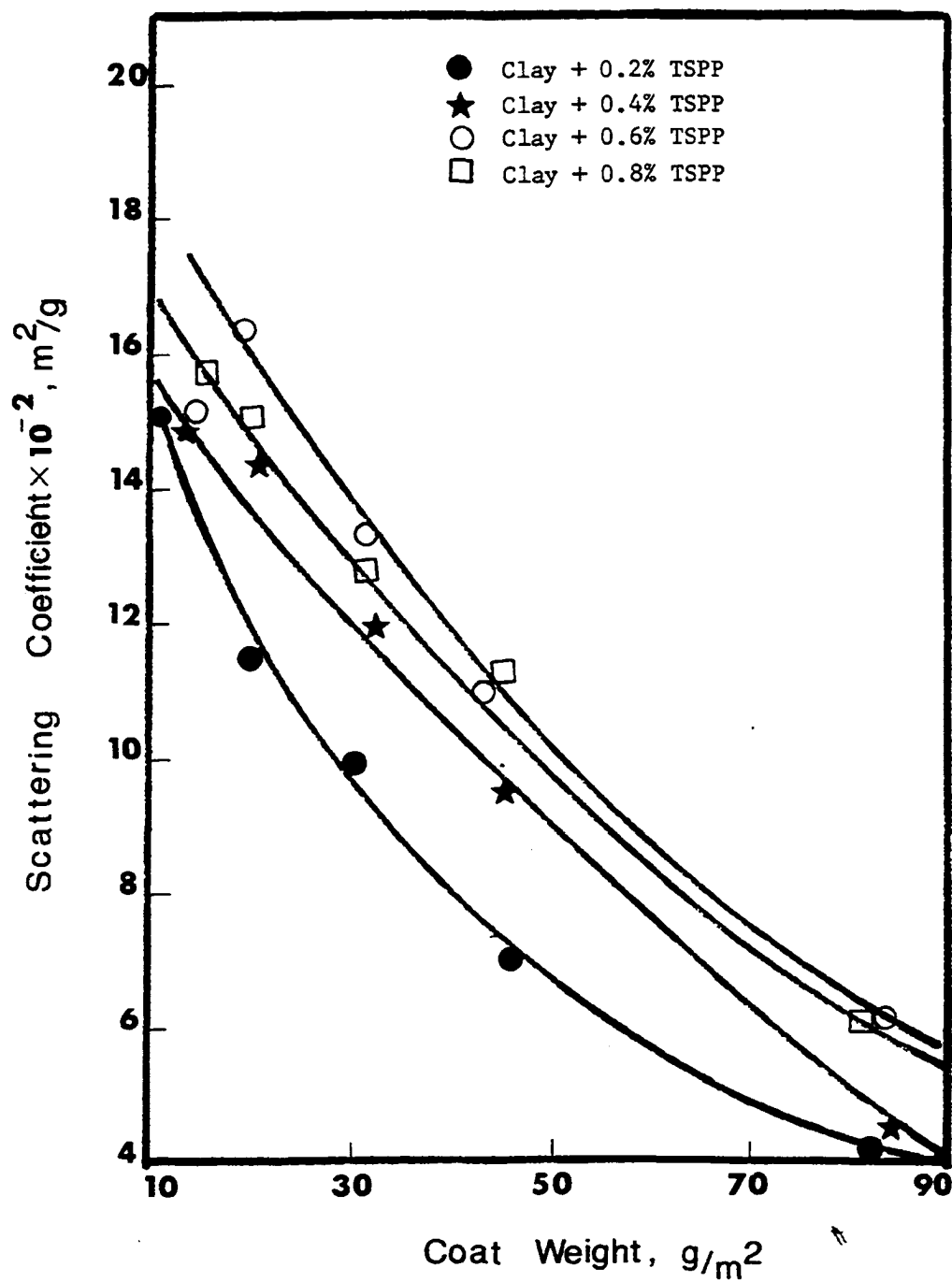


Fig.13

Effect of Coat Weight on Scattering Coefficient with Paper Substrate

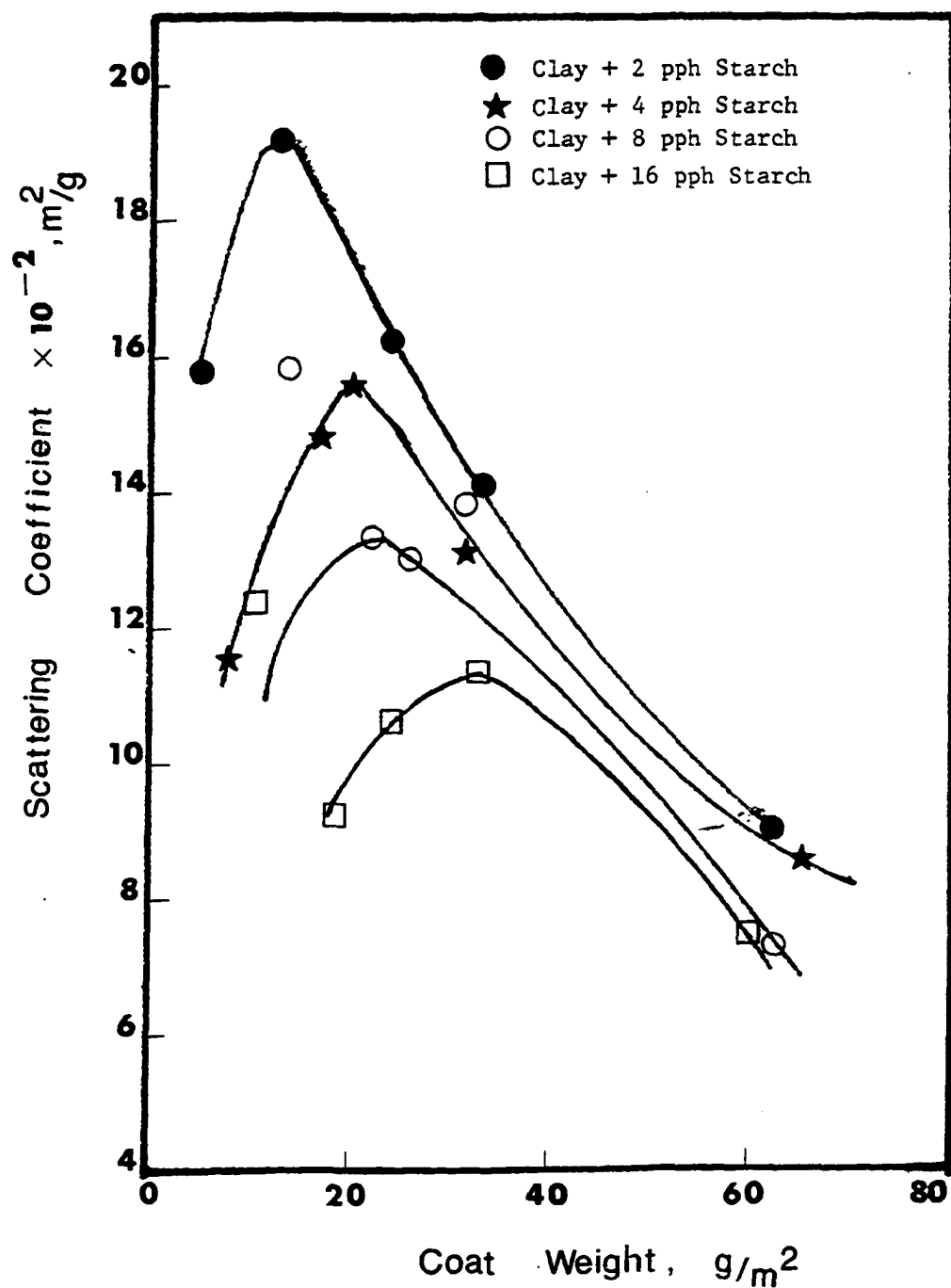


Fig.14

Effect of Coat Weight on Scattering Coefficient with Paper Substrate

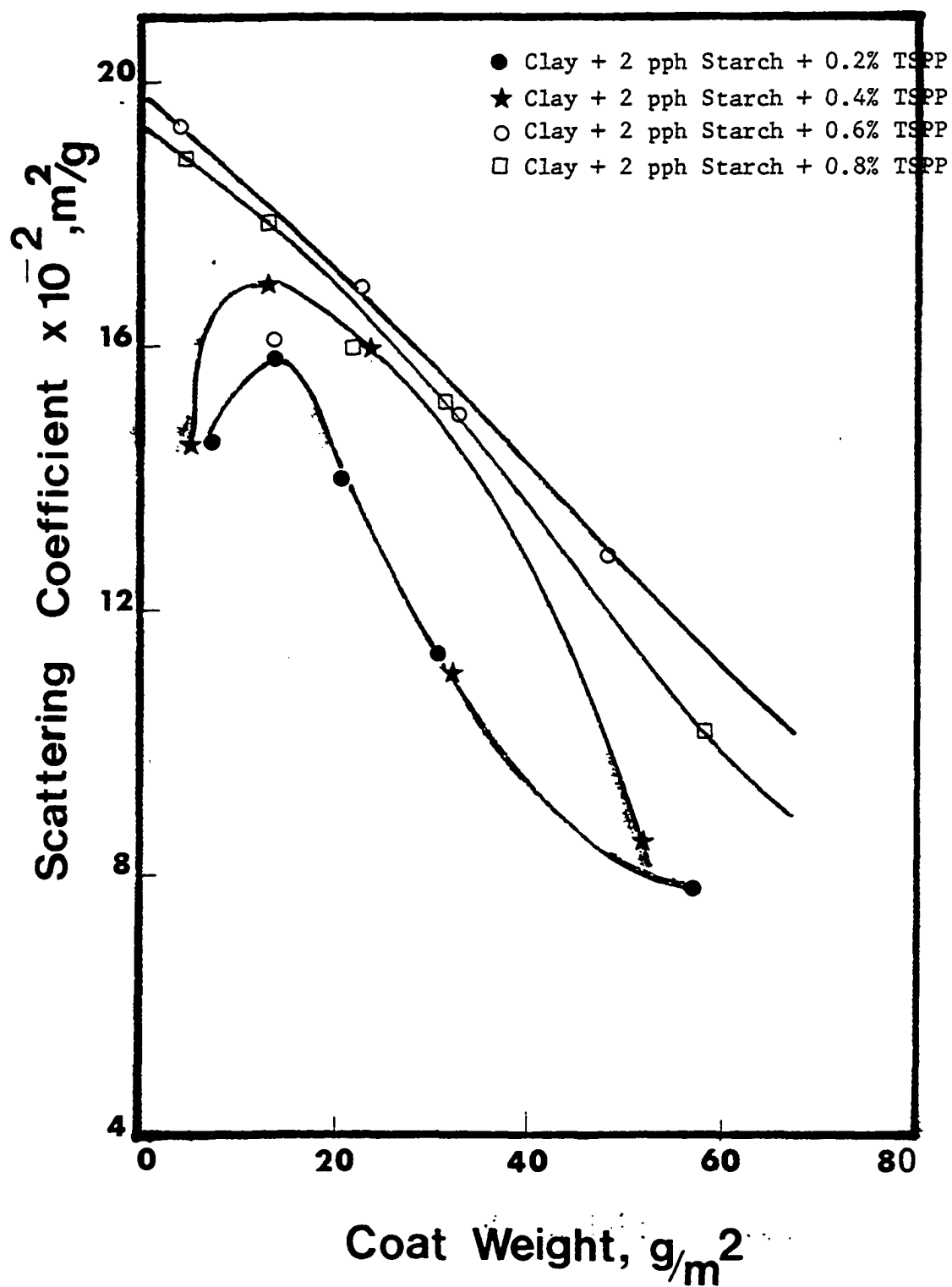


Fig.15

Effect of Coat Weight on Scattering Coefficient with Paper Substrate

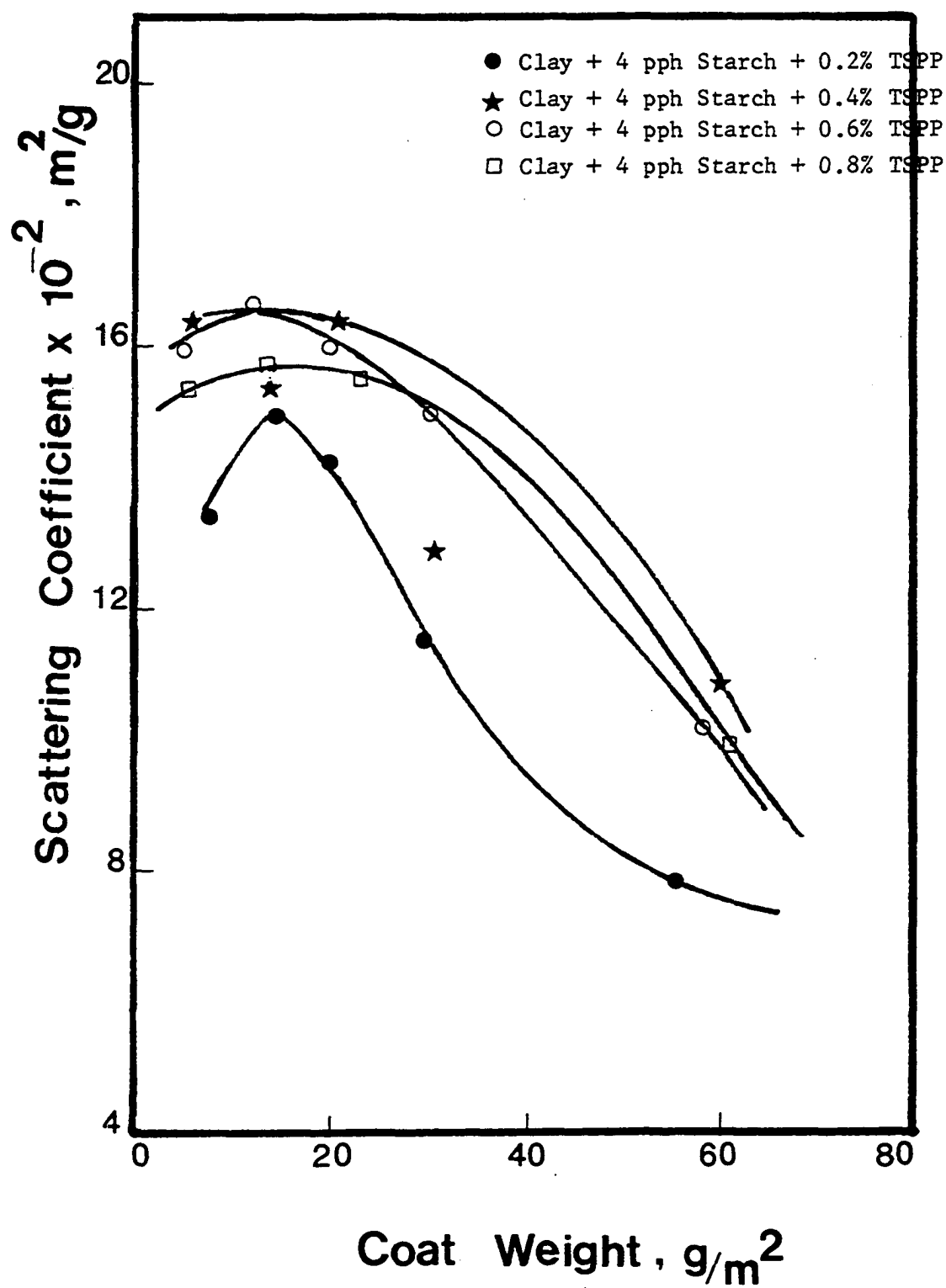


Fig.16

Effect of Coat Weight on Scattering Coefficient with Paper Substrate

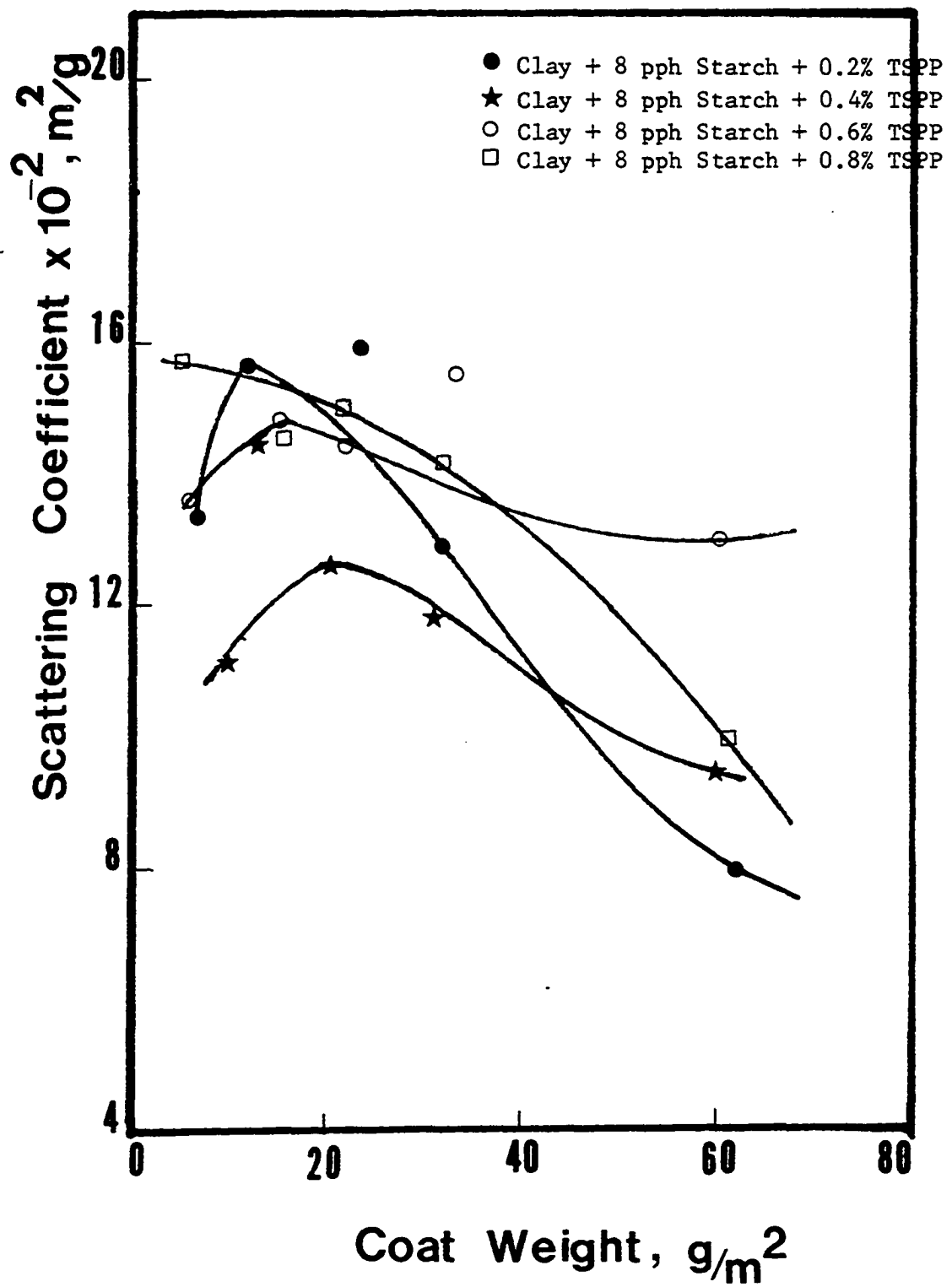
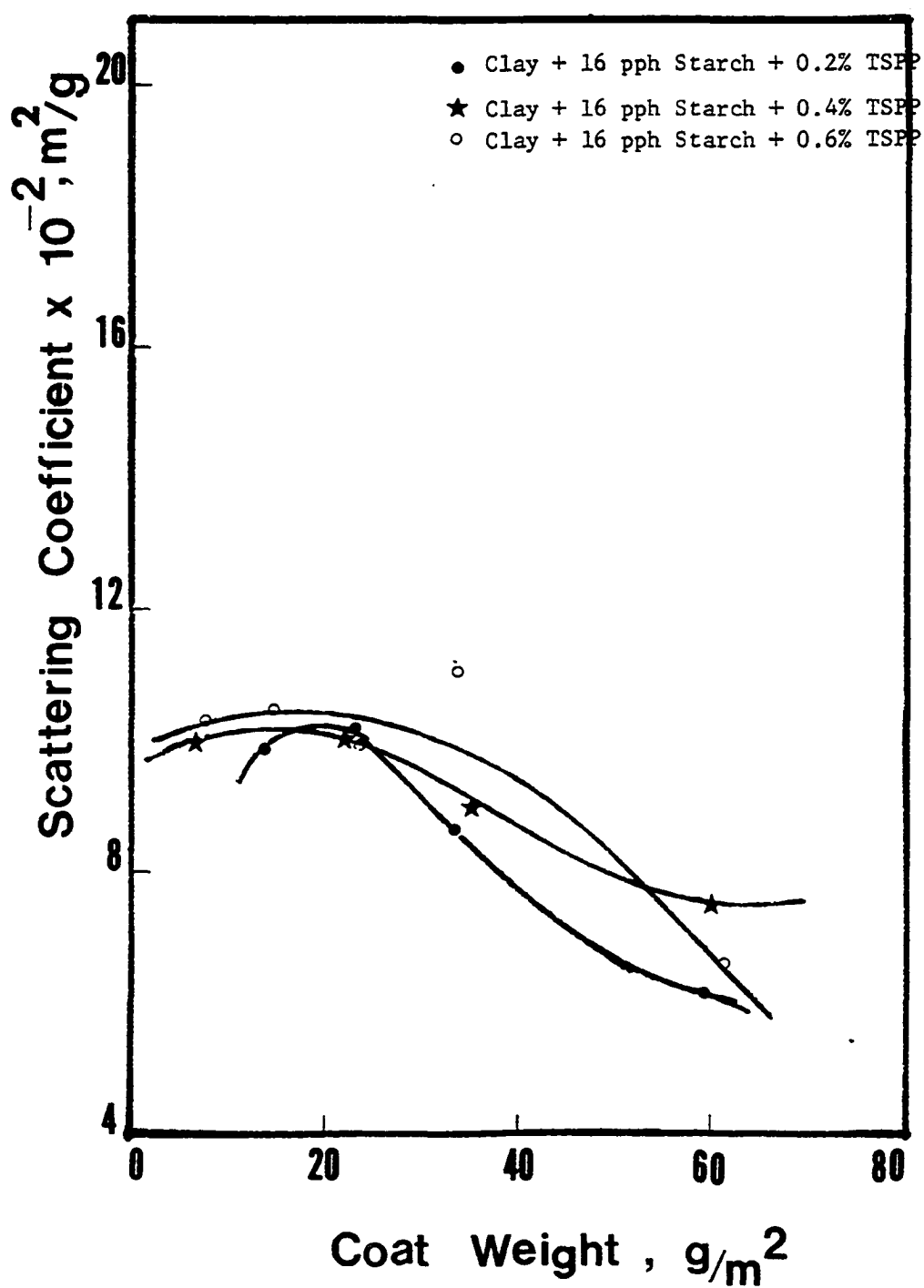


Fig.17

Effect of Coat Weight on Scattering Coefficient with Paper Substrate

**Fig.18**

Effect of Coat Weight on Scattering Coefficient with Paper Substrate

In the case of the black glass substrate (Figure 19) the scattering coefficient was decreased as the coat weight of the clay and TSPP system was increased. Different amounts of TSPP did not show any change in the scattering coefficient and all the points fell on the same curve. The same pattern of curves were obtained for the clay-starch systems. These did not show any change with different levels of starch. Different clay-starch-TSPP combinations followed the same pattern of curves except at 16 pph starch where the scattering coefficient curve was lowered. The decrease in scattering coefficient as coat weight increased can be due to reduced surface effect as discussed for paper.

There was disagreement between the two sets of scattering coefficient data calculated for the paper and black glass substrates. Since scattering differences were observed only in the paper substrate and not on the black glass, it could be possible that the different methods of calculating scattering coefficient give different values. Secondly, it could be possible that the pore volume and structure could be different on the substrates; this change in coating structure would affect scattering coefficient. The second factor is the most likely and will be discussed in a later section.

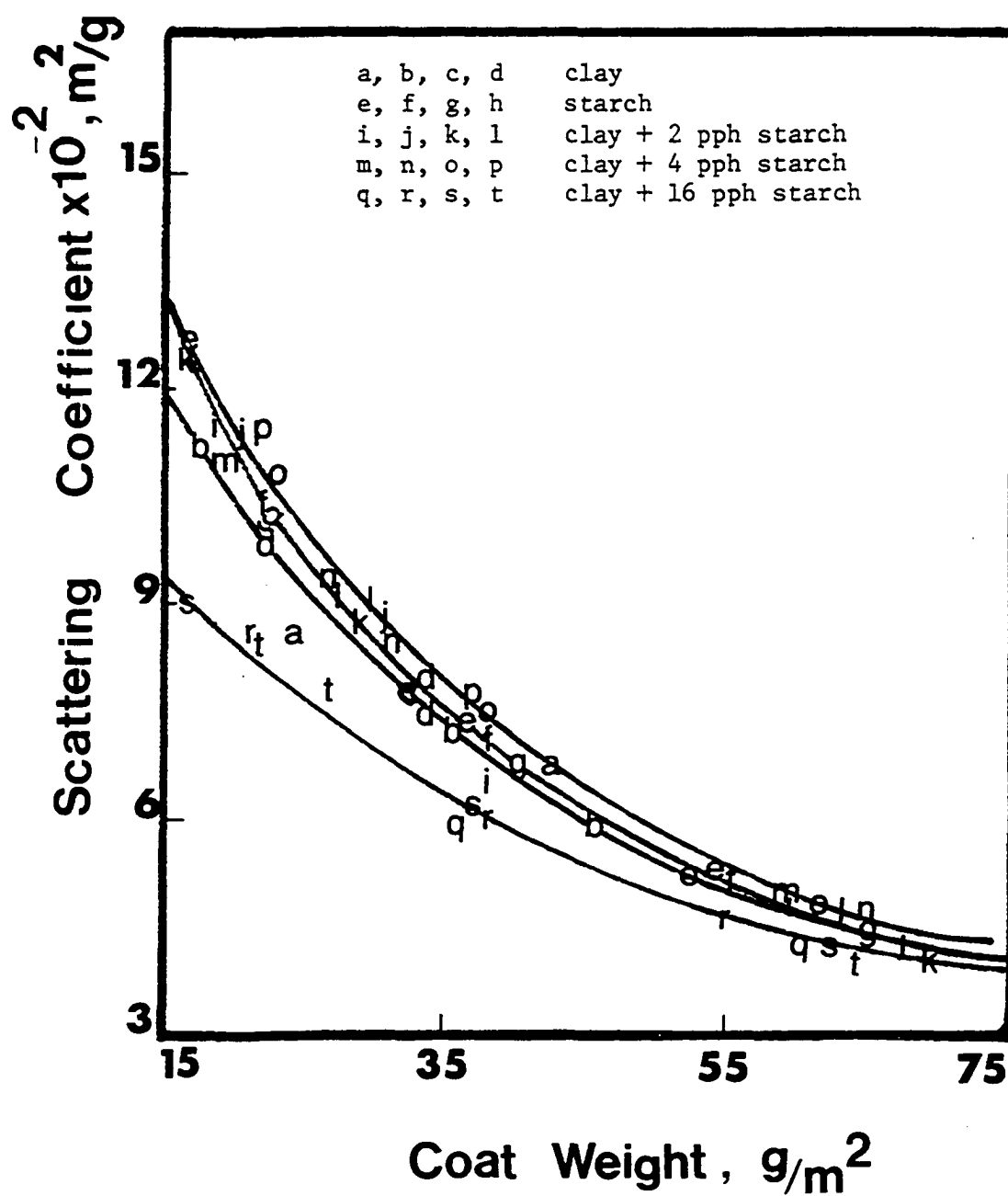


Fig.19

Effect of Coat Weight on Scattering Coefficient with Black Glass Substrate

Effects of TSPP and Starch on Scattering Coefficient
at Constant Coat Weight on Paper Substrate

In order to eliminate the coat weight effect, values for the scattering coefficient were obtained from the preceeding curves at 20 g/m² and plotted against percentage TSPP (Figure 20). The scattering coefficients of the clay systems were decreased by adding the deflocculating agent until approximately the same level which gave minimum viscosity of the coating (Figure 9), (0.2 and 0.13%, respectively). The addition of more TSPP increased the viscosity of the system as well as the scattering coefficient of the dried films.

Particles scatter the light at air interfaces. Packing in flocculated systems gives more air surfaces than in well-dispersed systems. Accordingly, in flocculated systems there should be more air surfaces to scatter the light which could give higher scattering in dried films. As the dispersing agent is added, the agglomerates in the liquid dispersion would be broken and in the resultant dried film the air interface area would be reduced, resulting in a reduction of the scattering coefficient. This was observed until viscosity reached a minimum. Above this level of TSPP or starch addition, the dispersion viscosity increased indicating agglomeration. The dried films made from these dispersions also showed increased agglomeration through an increase in scattering coefficient.

Previous work has been done by Trader (15), Hemstock and Bergman (5), and Kaliski (14), showing the effect of packing on the scattering coefficient. Trader (15) calculated the scattering

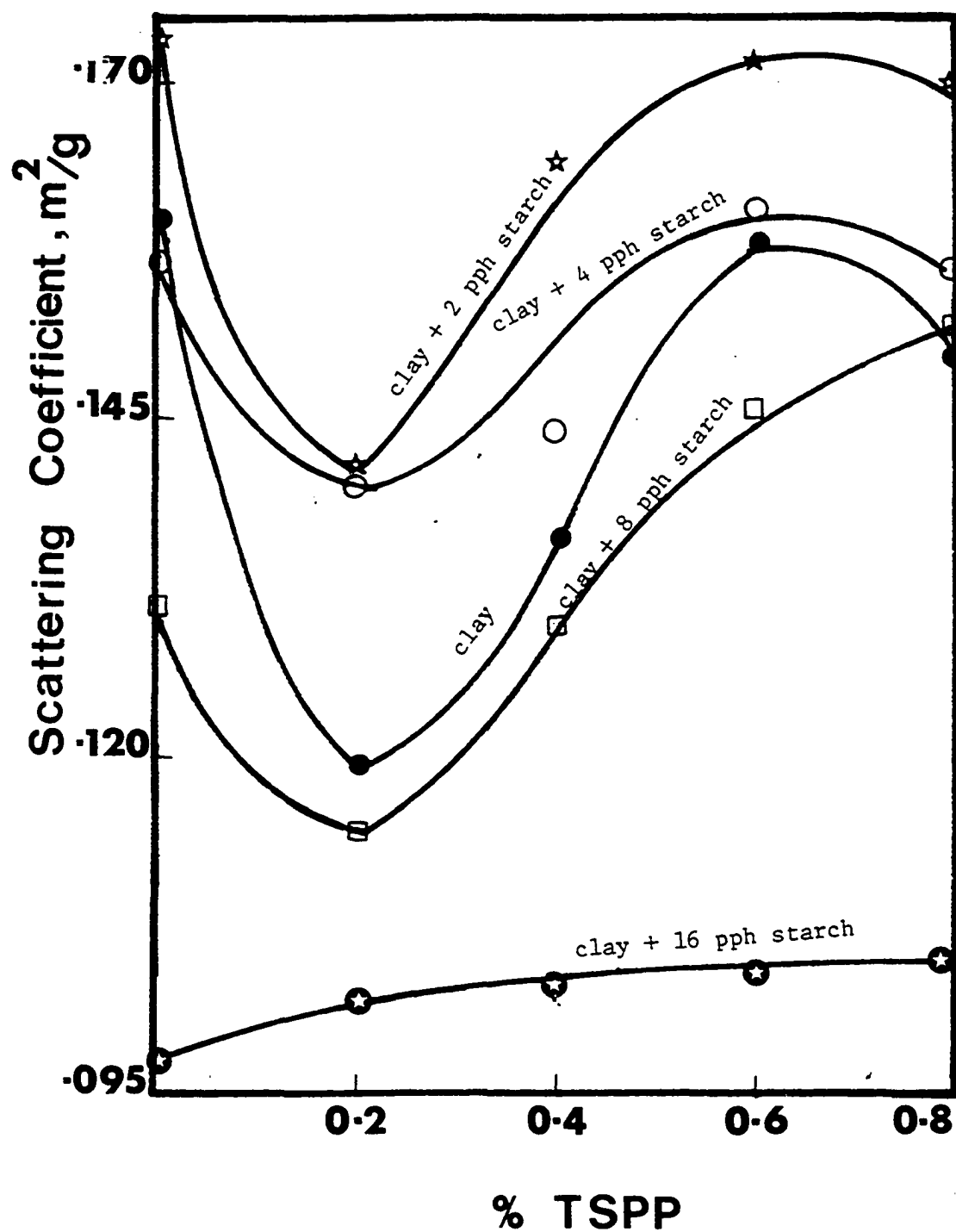


Fig.20

Effect of TSPP on Scattering Coefficient at Constant Coat Weight
(20 g/m^2) with Paper Substrate

coefficient for different particle size clays and showed that they were particle size dependent. Hemstock and Bergman's (5) work does correlate with these results, in that they added different amounts of TSPP to the clay slip and measured the film porosity. The film porosity was decreased until the minimum viscosity was reached and then increased along with the mean hydraulic pore radius. When the system was flocculated the pore radius size was large due to the larger agglomerates and pore radius became smaller as the agglomerates were broken down by adding the dispersing agent. Pore radius started to increase as the system was overdispersed. Kaliski (14) indicated that the scattering coefficient of a coating film containing a binder level of practical significance was higher for #1 clay than #2 and MD clay. Thus, the above authors showed that particle size and its packing was one of the variables which was effecting the scattering coefficient of the coating.

When the starch was added to the slip, the same trend was obtained as in the clay-water system, except at the high level of starch. The 2 pph starch gave a higher curve than clay, but it shifted lower as the amount of starch was increased. At 16 pph starch there was a negligible change in the scattering coefficient by adding the different levels of dispersing agent.

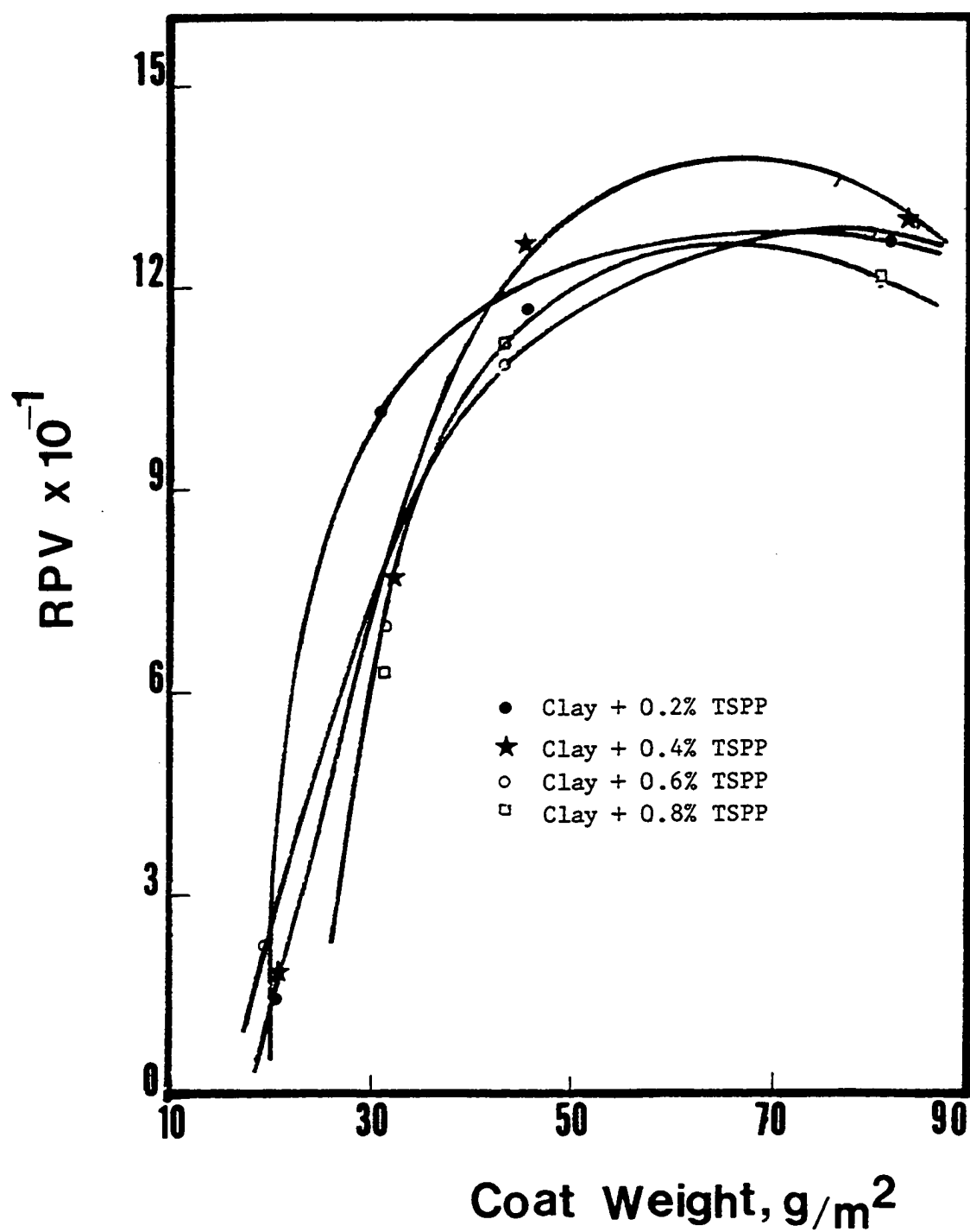
First of all let us consider why the scattering coefficient curve was shifted up by adding starch to the clay-TSPP system. Later data will show that the addition of starch increased relative pore volume which could indicate expansion of the film structure

and therefore an increase in scattering coefficient. However, decreased scattering coefficient at higher starch levels could be due to reduced refractive index differences between the pigment and binder as starch-pigment interfaces replaced pigment-air interfaces. The large drop in scattering coefficient at 16 pph starch could be due to a combination of relative pore volume drop and refractive index difference reduction.

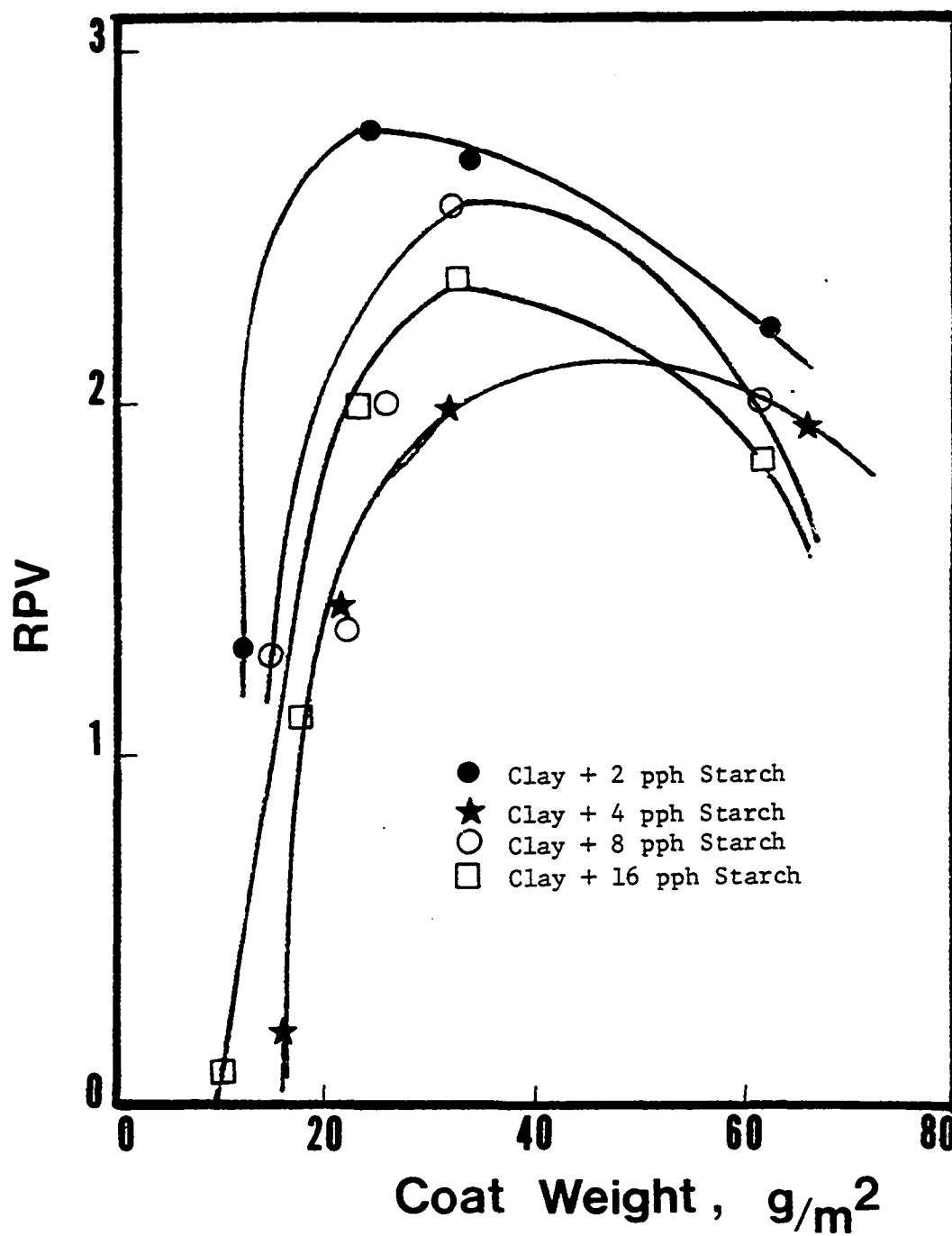
Effects of TSPP and Starch on Relative Pore Volume
of Coatings on Paper and Black Glass

The relative pore volume of the coating was calculated from the experimental film thickness and coat weight data, as well as theoretical density. It should be noted that Kaliski (14) calculated the relative pore volume of pigment-adhesive system, but he considered the idealized void filling hypothesis and assumed that coating structure was determined primarily by the packing characteristics of the pigment, independent of the adhesive present. The adhesive, then, in developing the film strength, would only fill in the voids. Burke (6) and Grafton (7) have shown that the hypothesis of dealized void filling is not completely valid for any of the pigment-adhesive systems. So for this work, when the relative pore volume was calculated, the starch was considered in the calculations. Appendix II gives a sample calculation using both methods.

The coat weight vs. relative pore volume data was plotted (Figures 21-26) for all coatings on the paper substrate. The relative pore volume in all cases increased with coat weight up to a certain level and then leveled out or decreased. For the black glass substrate, the same types of plots (Figures 27-32) did not give the same graphic relationships as did the paper substrate. For the black glass, the relative pore volume generally decreased as the coat weight was increased.

**Fig.21**

Effect of Coat Weight on Relative Pore Volume with Paper Substrate

**Fig.22**

Effect of Coat Weight on Relative Pore Volume with Paper Substrate

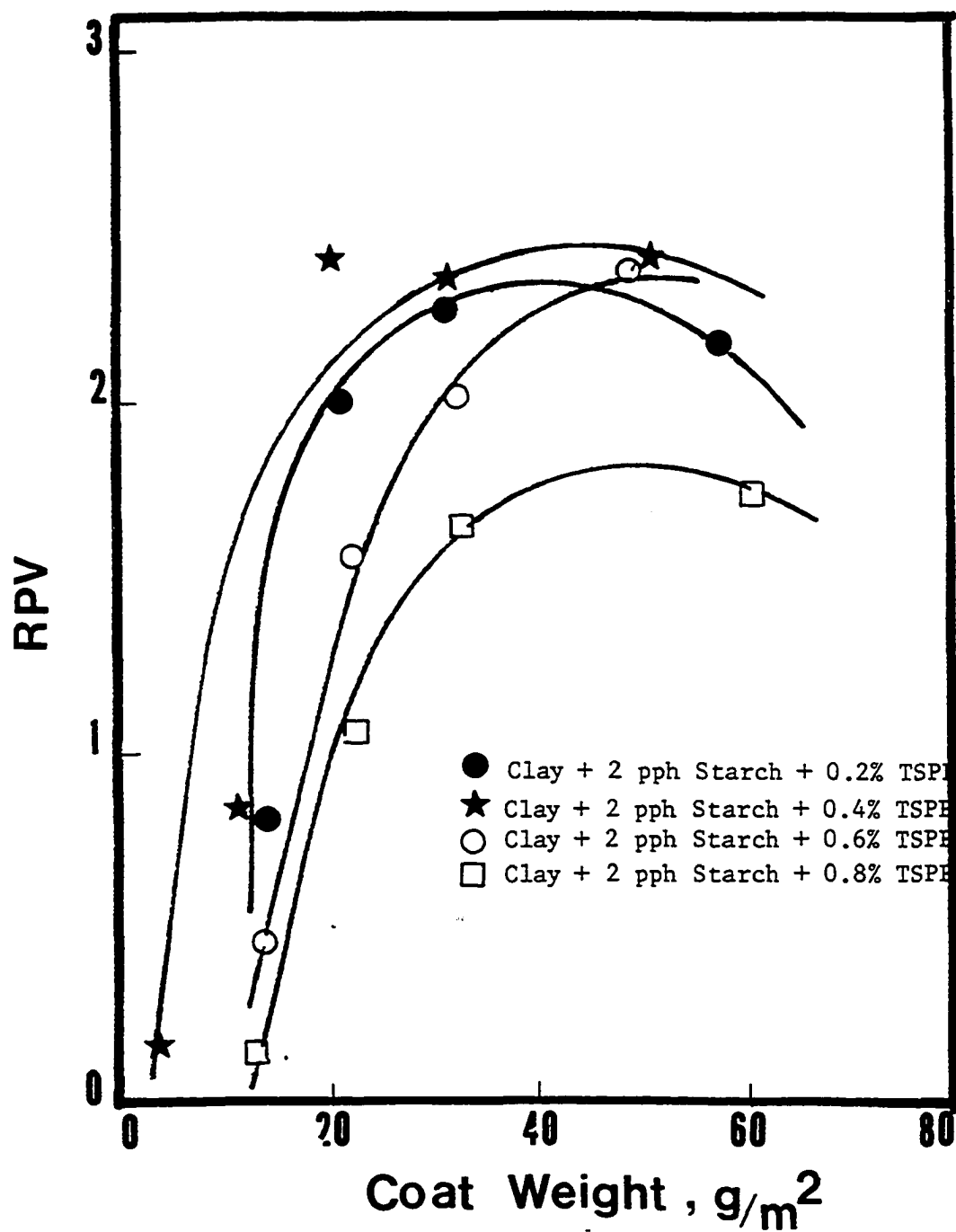
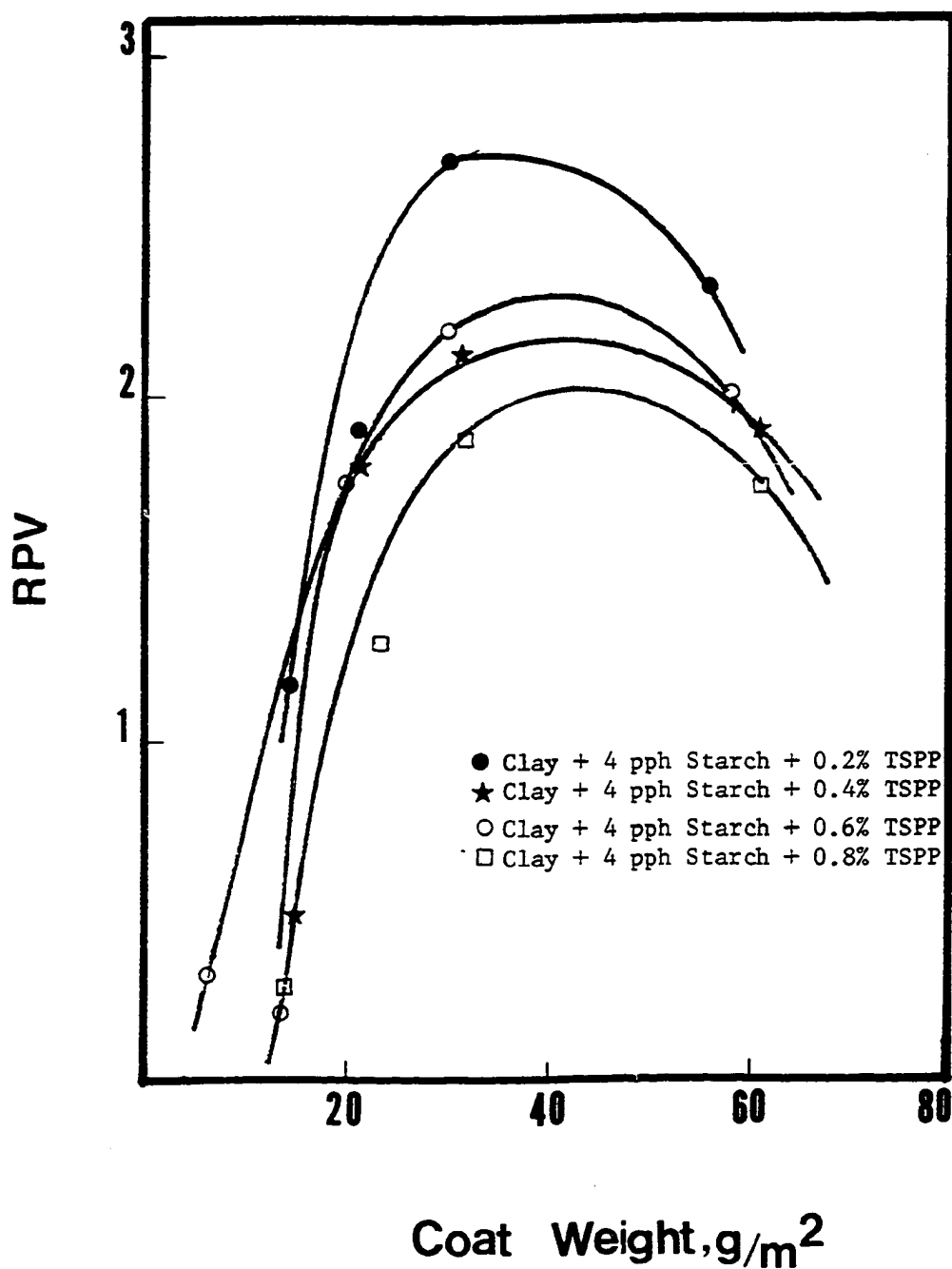
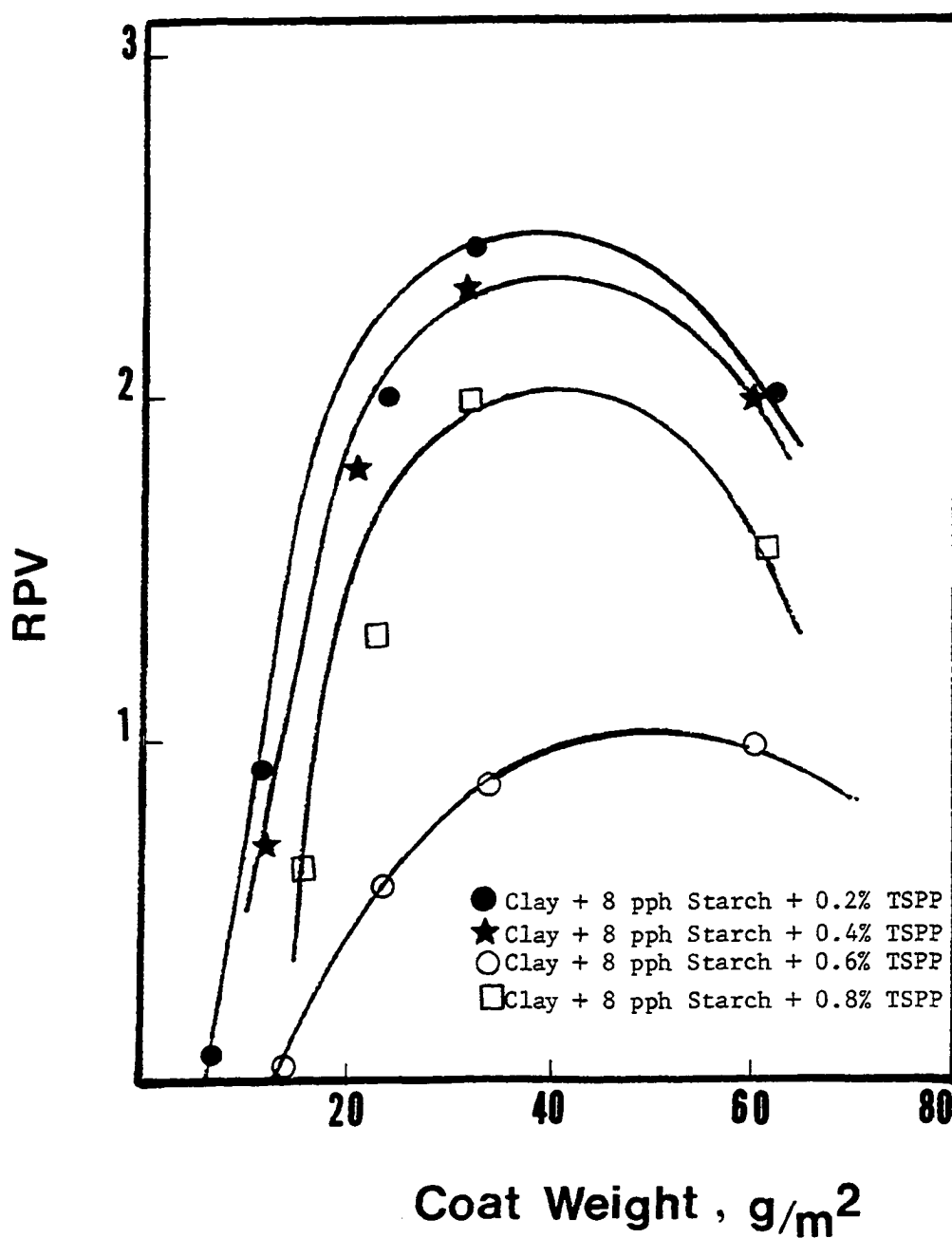


Fig. 23

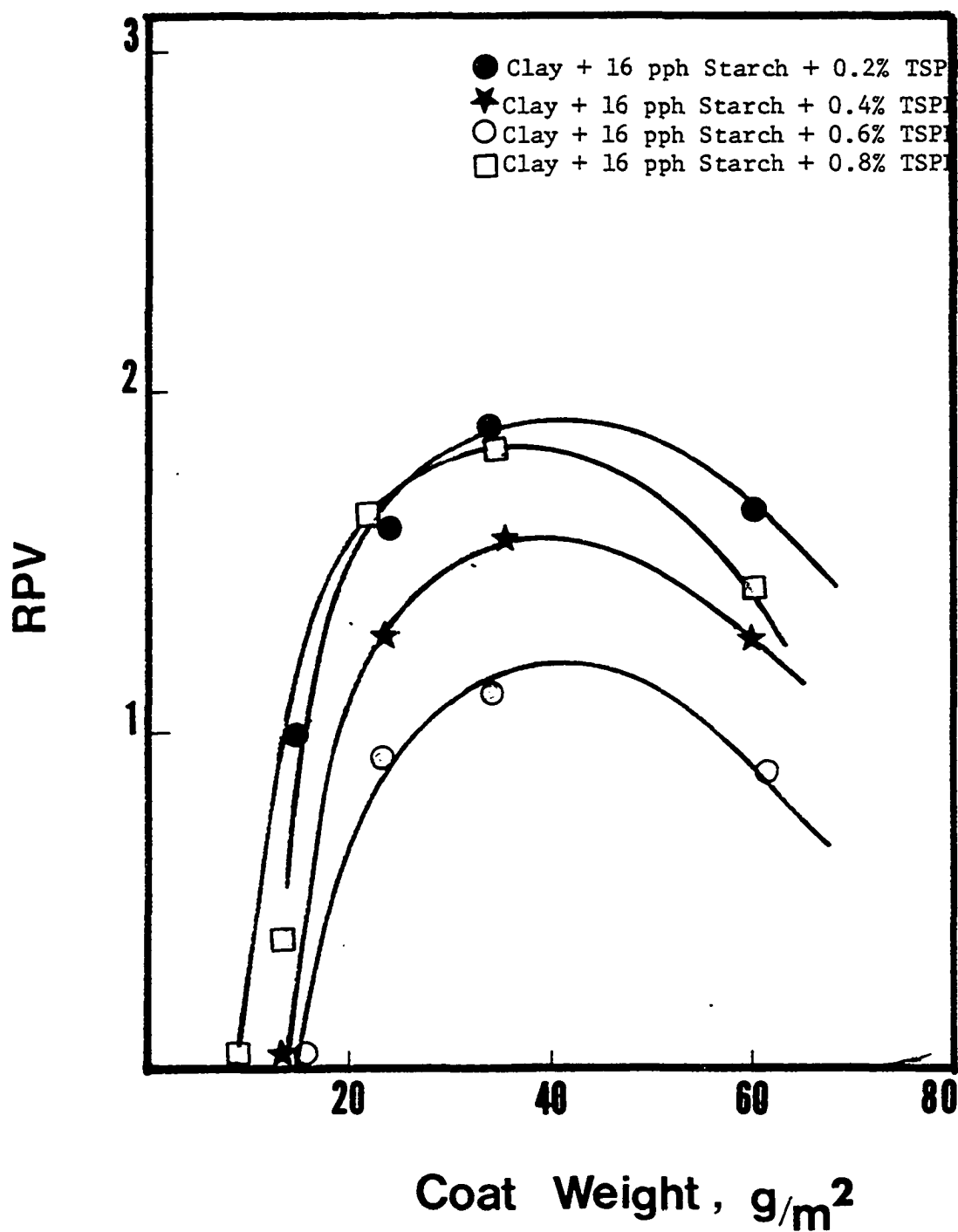
Effect of Coat Weight on Relative Pore Volume with Paper Substrate

**Fig.24**

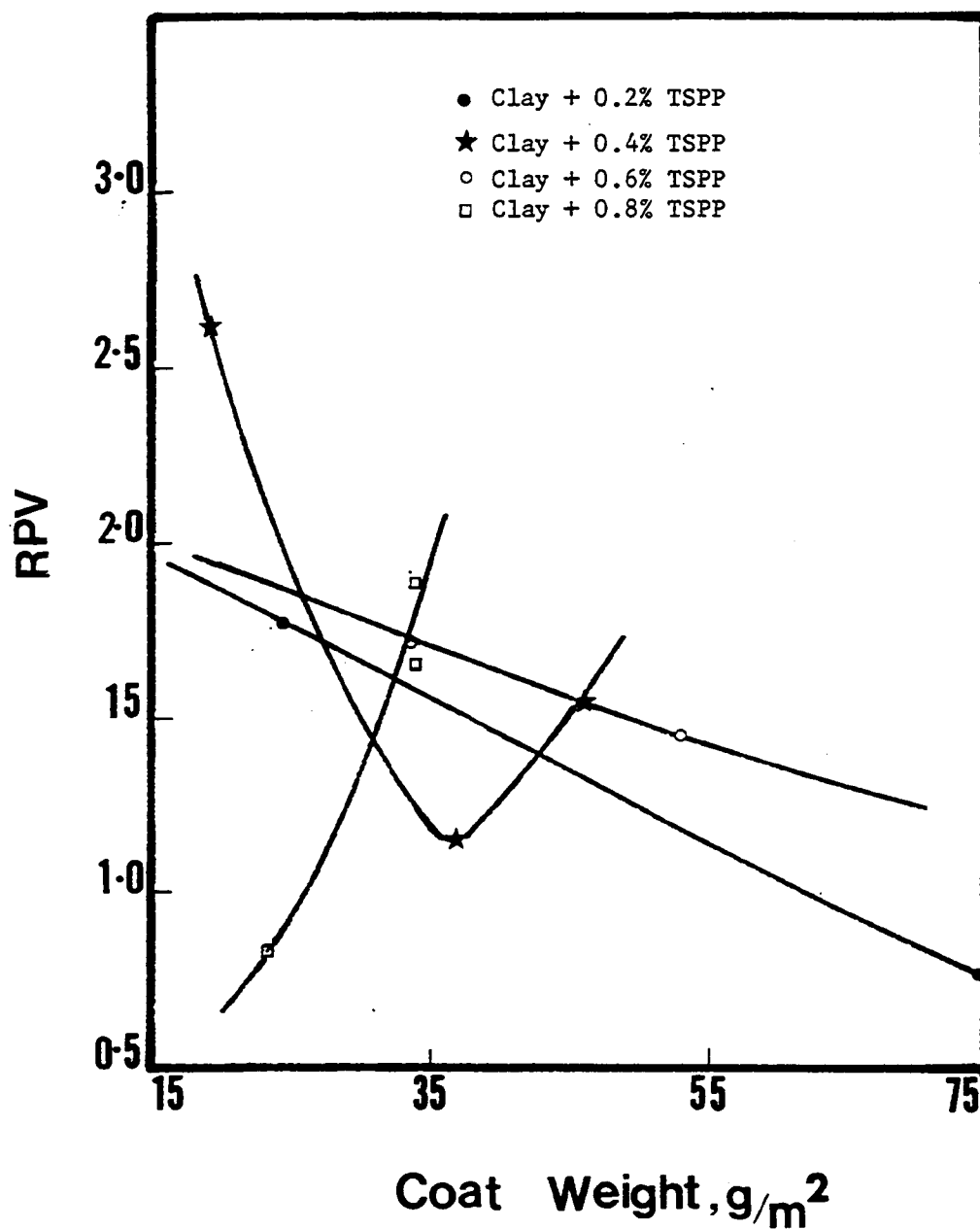
Effect of Coat Weight on Relative Pore Volume with Paper Substrate

**Fig.25**

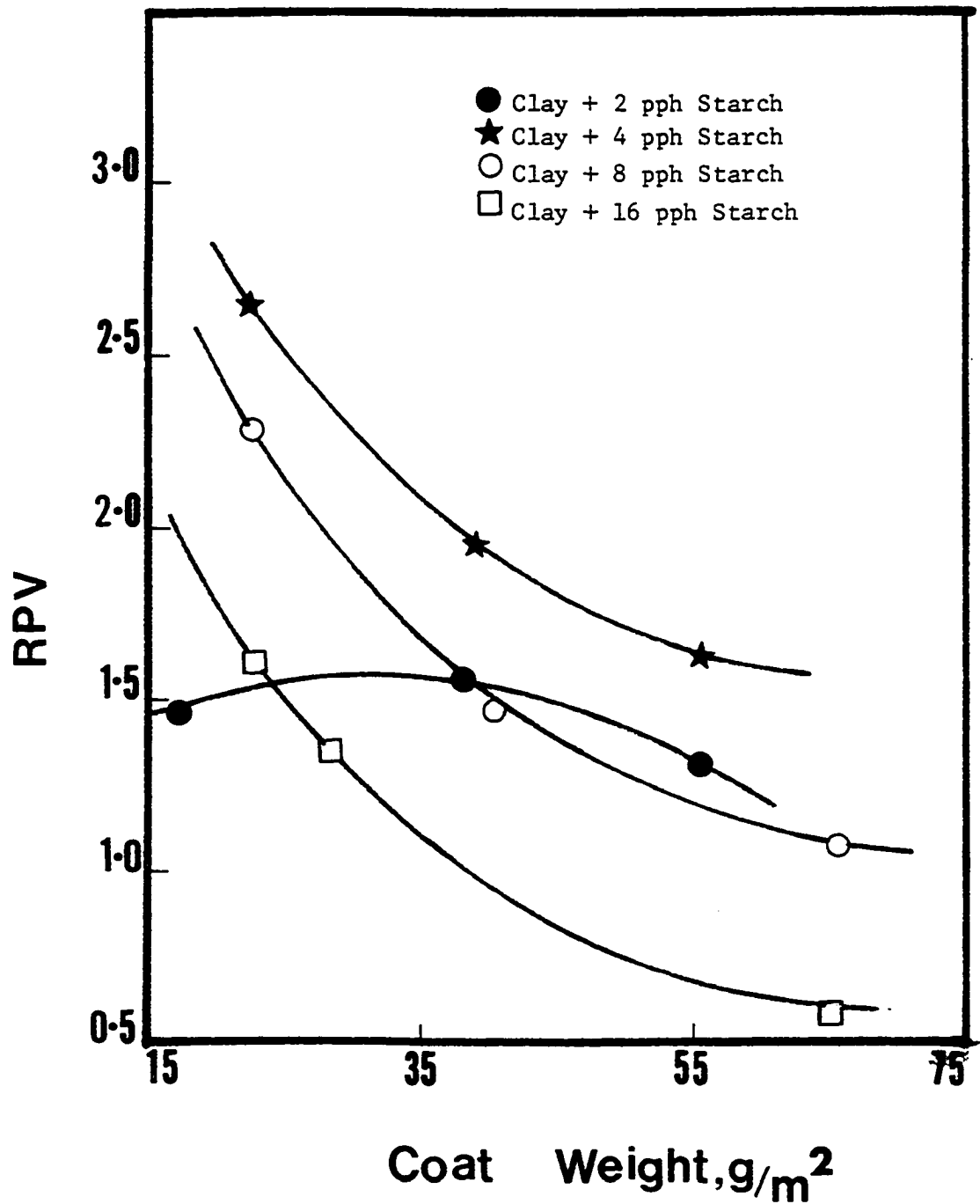
Effect of Coat Weight on Relative Pore Volume with Paper Substrate

**Fig.26**

Effect of Coat Weight on Relative Pore Volume with Paper Substrate

**Fig.27**

Effect of Coat Weight on Relative Pore Volume with Black Glass Substrate

**Fig. 28**

Effect of Coat Weight on Relative Pore Volume with Black Glass Substrate

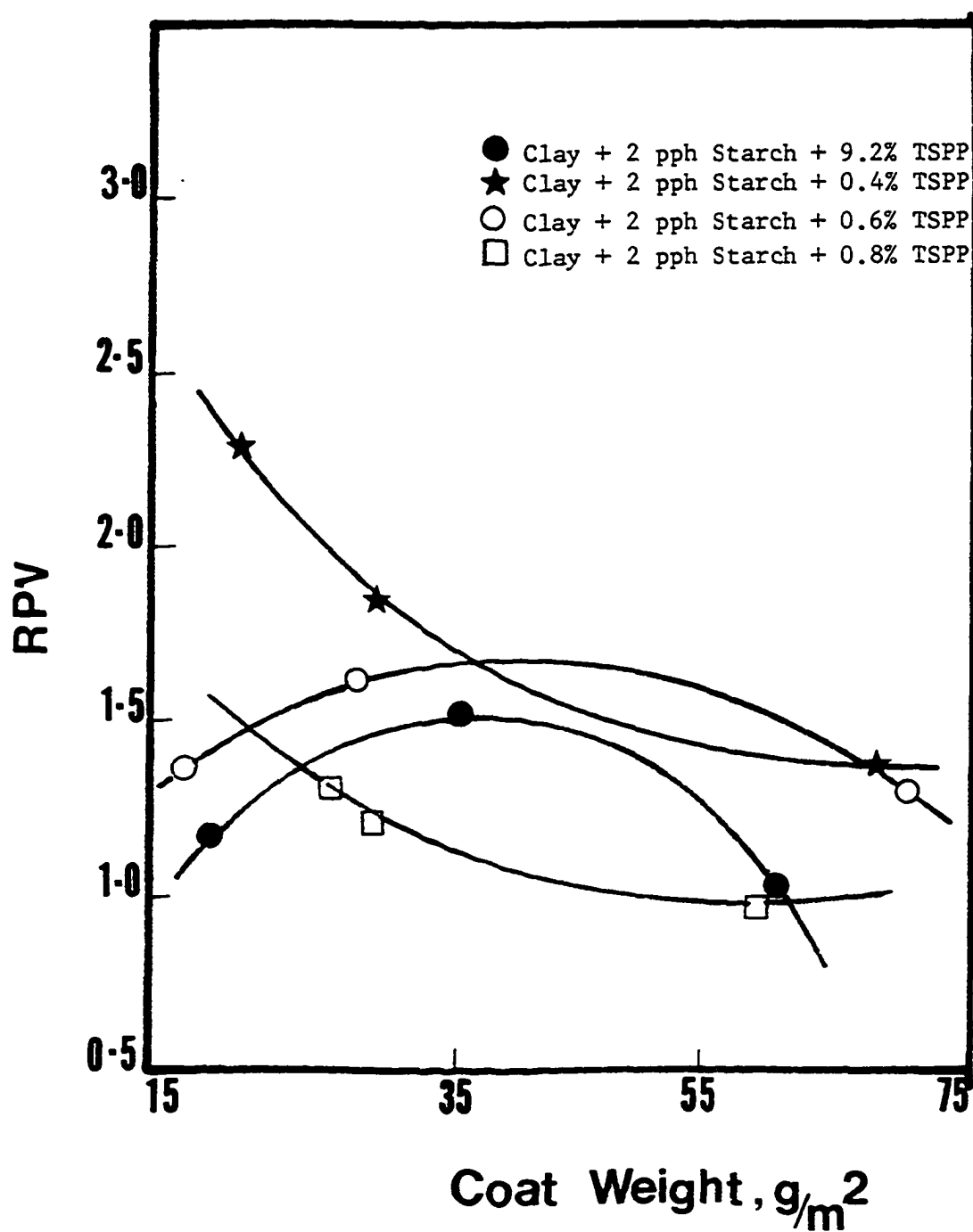


Fig.29

Effect of Coat Weight on Relative Pore Volume with Black Glass Substrate

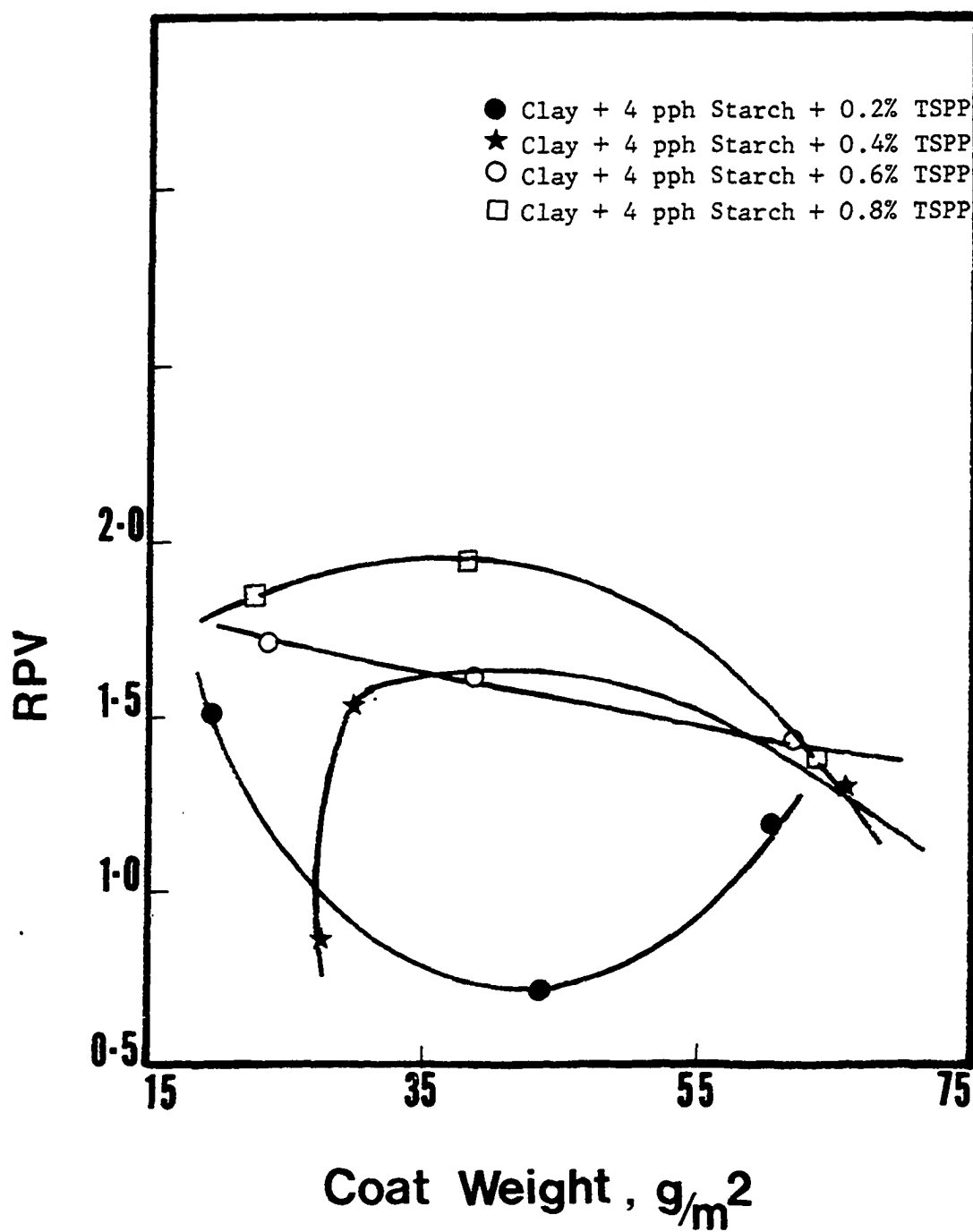


Fig.30

Effect of Coat Weight on Relative Pore Volume with Black Glass Substrate

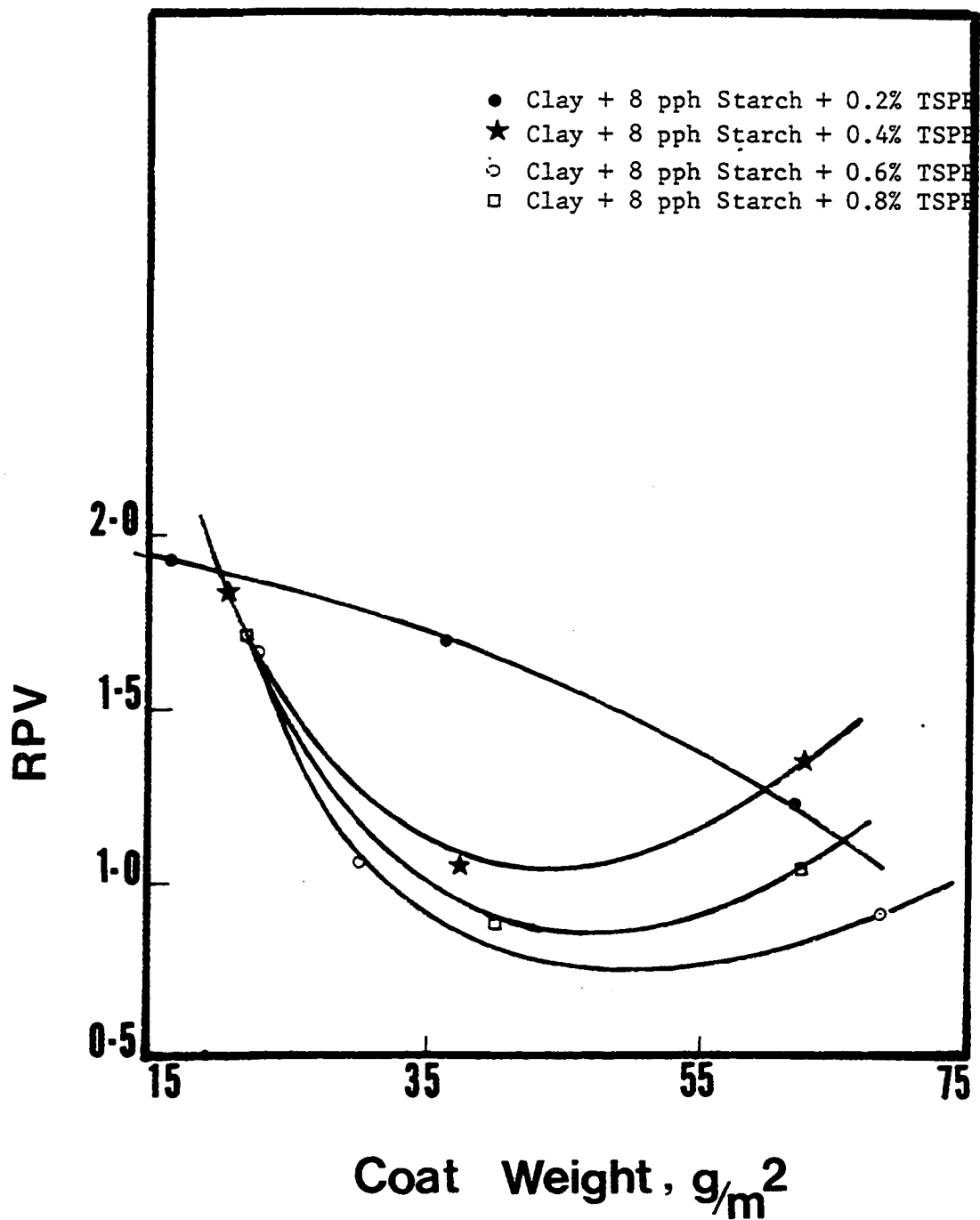


Fig.31

Effect of Coat Weight on Relative Pore Volume with Black Glass Substrate

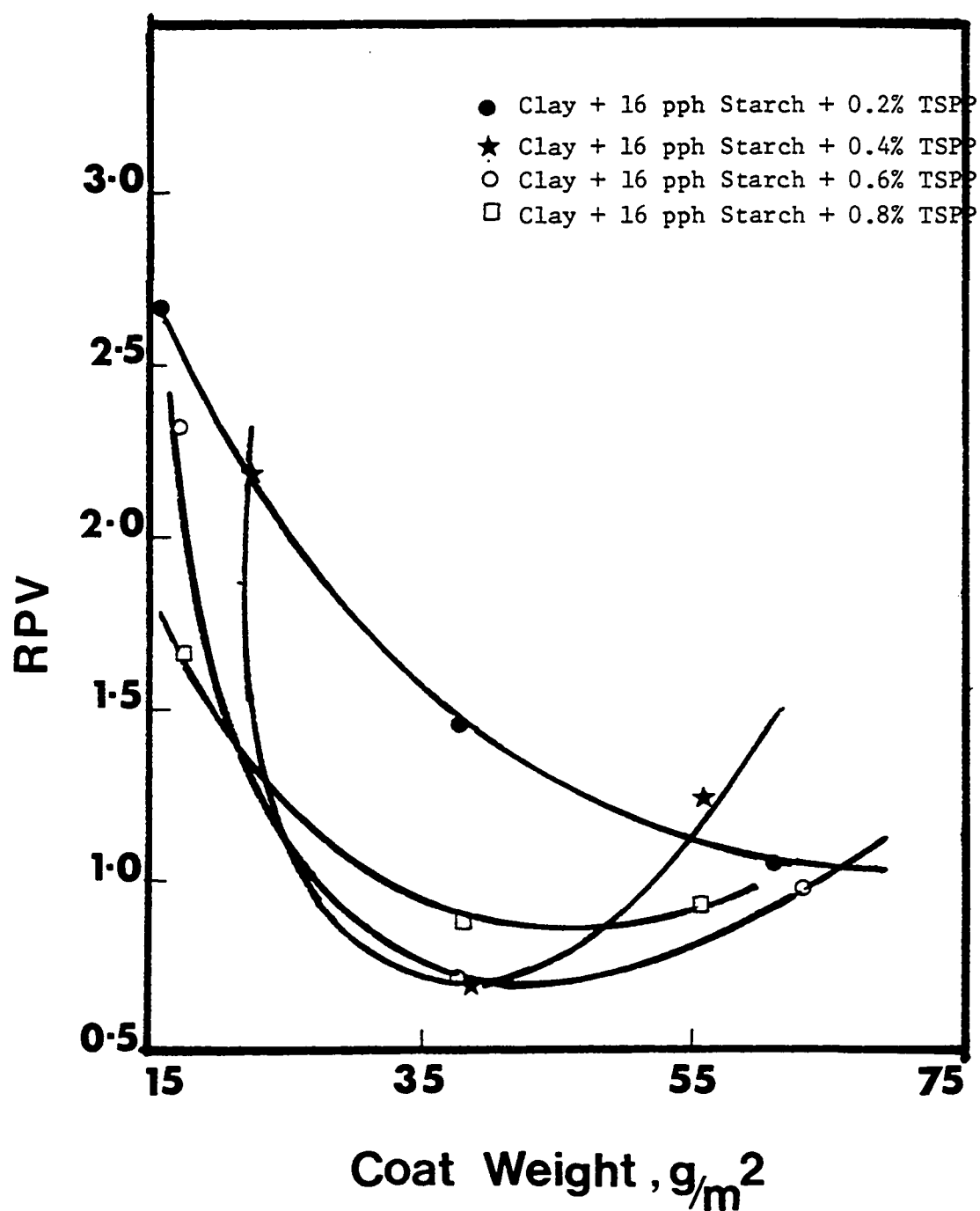


Fig.32

Effect of Coat Weight on Relative Pore Volume with Black Glass Substrate

In Figure 33 the relative pore volume is plotted against the percentage TSPP at constant coat weight (25 g/m^2) on the paper substrate. In the clay system when TSPP was added, the relative pore volume increased then decreased. When starch was added, the RPV curves were shifted upward for 2, 4, and 8 pph starch, with all curves being very similar in value. However, the 16 pph starch curve behaved differently from the others. In that case, RPV decreased to 0.6% TSPP and then increased as more TSPP was added.

Similarly, the relative pore volume was obtained for coatings on the black glass substrate, and the relative pore volume was plotted against percent TSPP (Figure 34). All the curves were scattered and did not show any resemblance between each other as did those on the paper substrate (Figure 33).

Reviewing all the graphs (Figures 21-32) and the above discussion, it appears that the coating structure itself was different on the paper and black glass substrates. The coating structure could be responsible for the discrepancies between the two sets of scattering coefficient data for the paper and black glass substrates.

There could be two reasons for having different coating structure on the paper and black glass substrate. First, the paper substrate could have absorbed some water which could have changed the arrangement of the particles and adhesive, while there was no absorption in the case of the black glass. Second, surface smoothness could have affected film formulation since the glass is smoother than the paper.

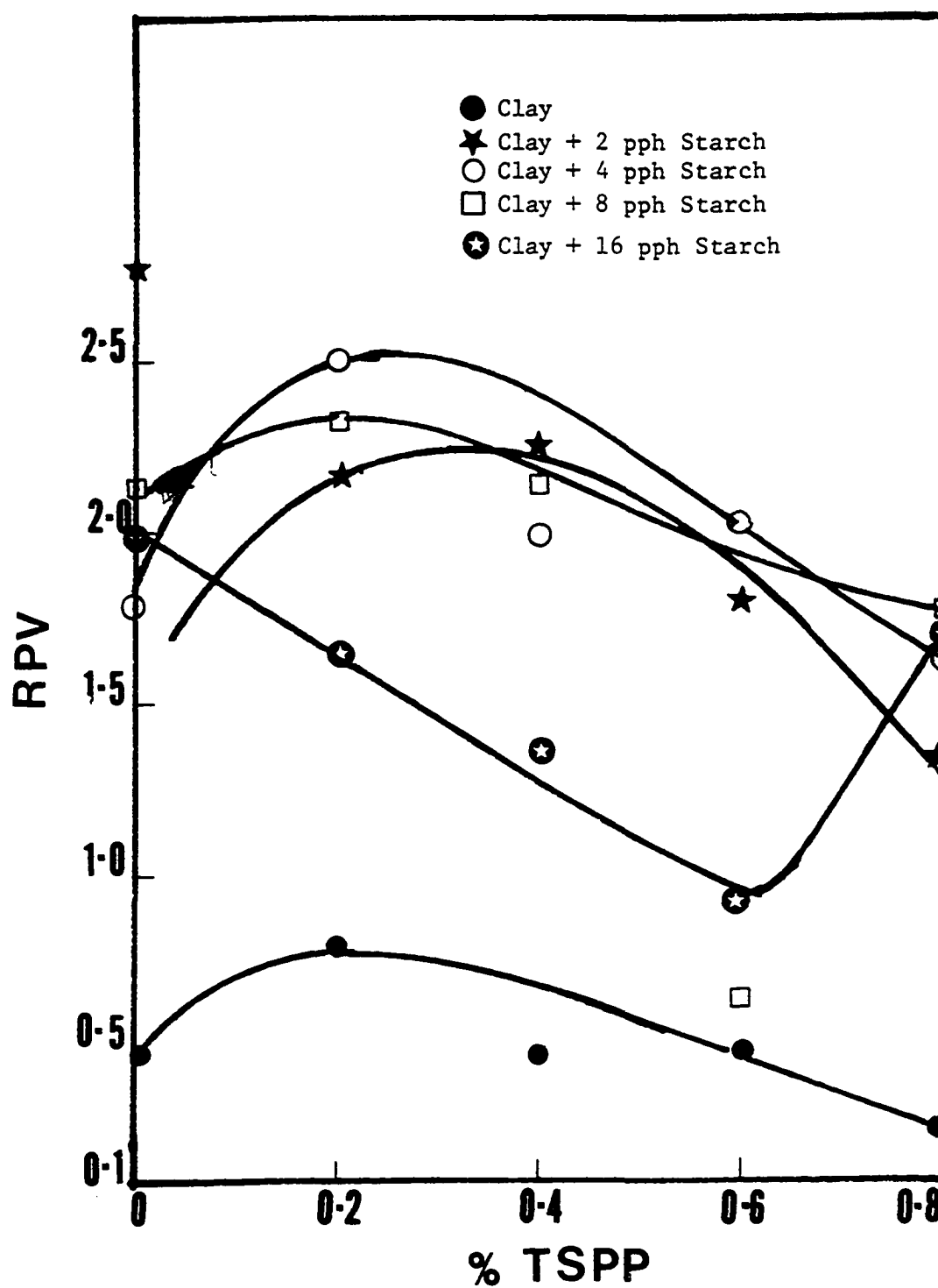


Fig. 33

Effect of TSPP on Relative Pore Volume at Constant Coat Weight (25 g/m^2) with Paper Substrate

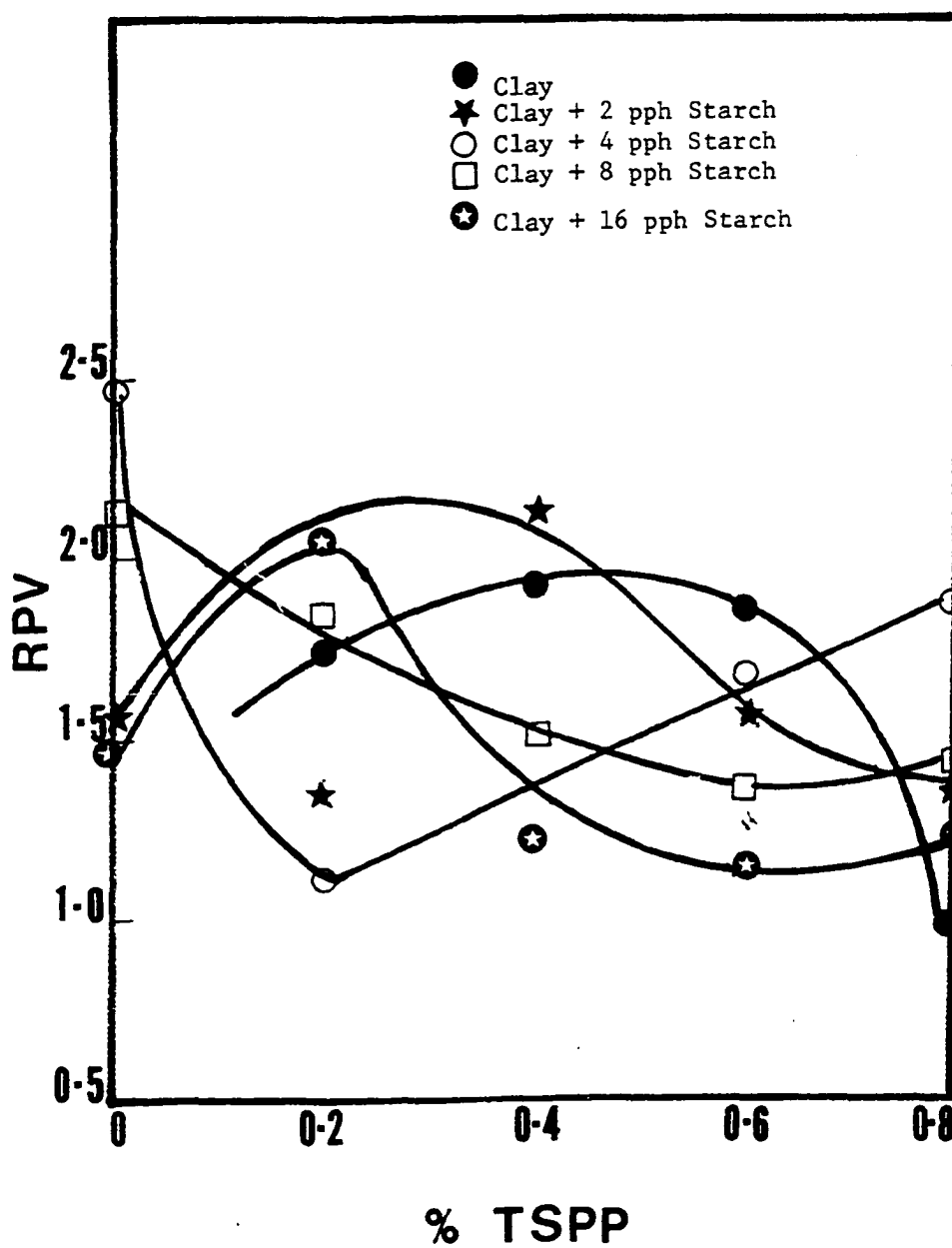


Fig.34

Effect of TSPP on Relative Pore Volume at Constant Coat Weight (25 g/m^2) with Black Glass Substrate

The Cobb size test was run on the paper substrate and time vs. water absorbed (g/m^2) was plotted (Figure 35), showing that the paper absorbed a considerable amount of water. Since the heavy coat weights took over 15 minutes to air dry, this absorption could have affected coating structure as the coating dried.

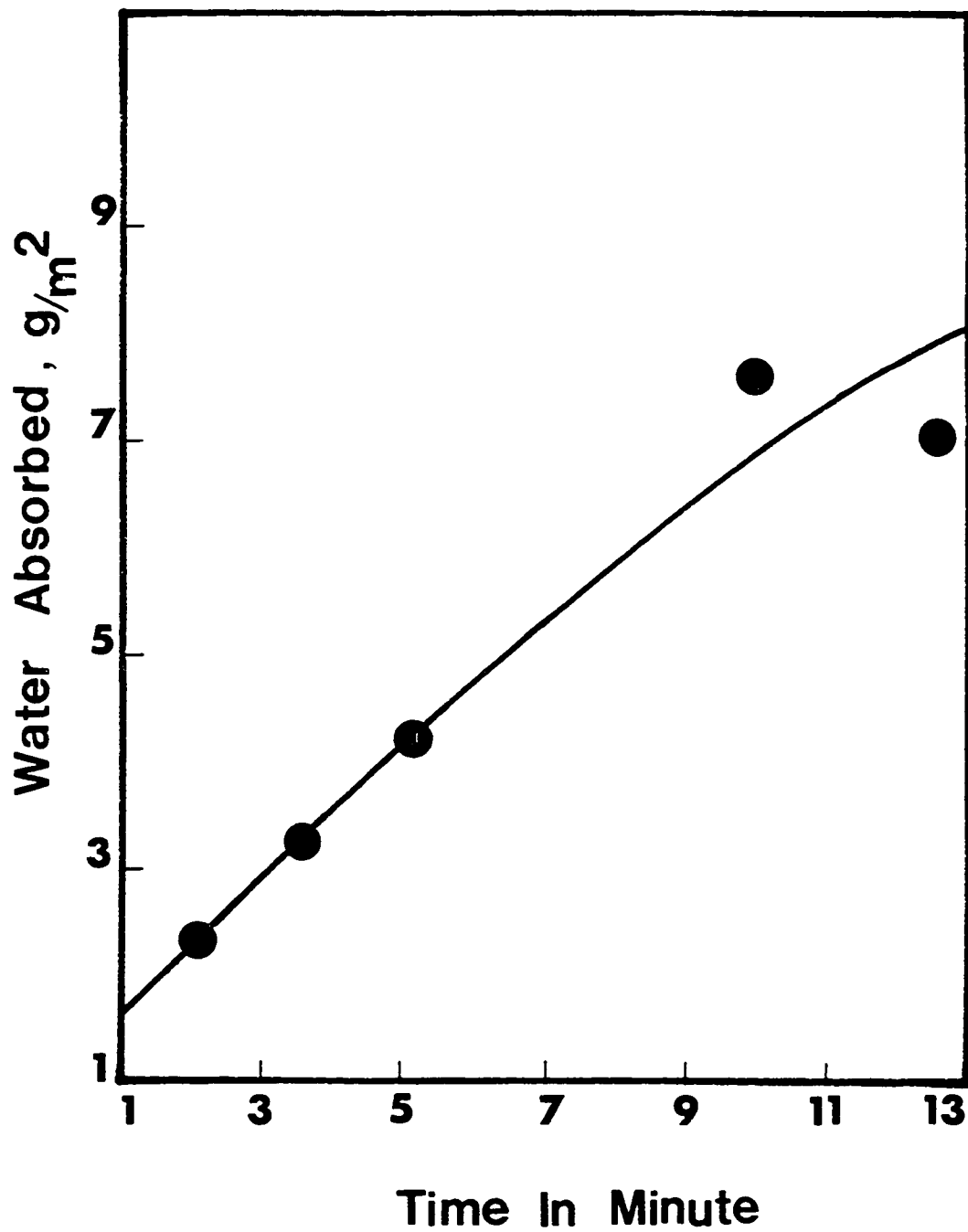


Fig.35

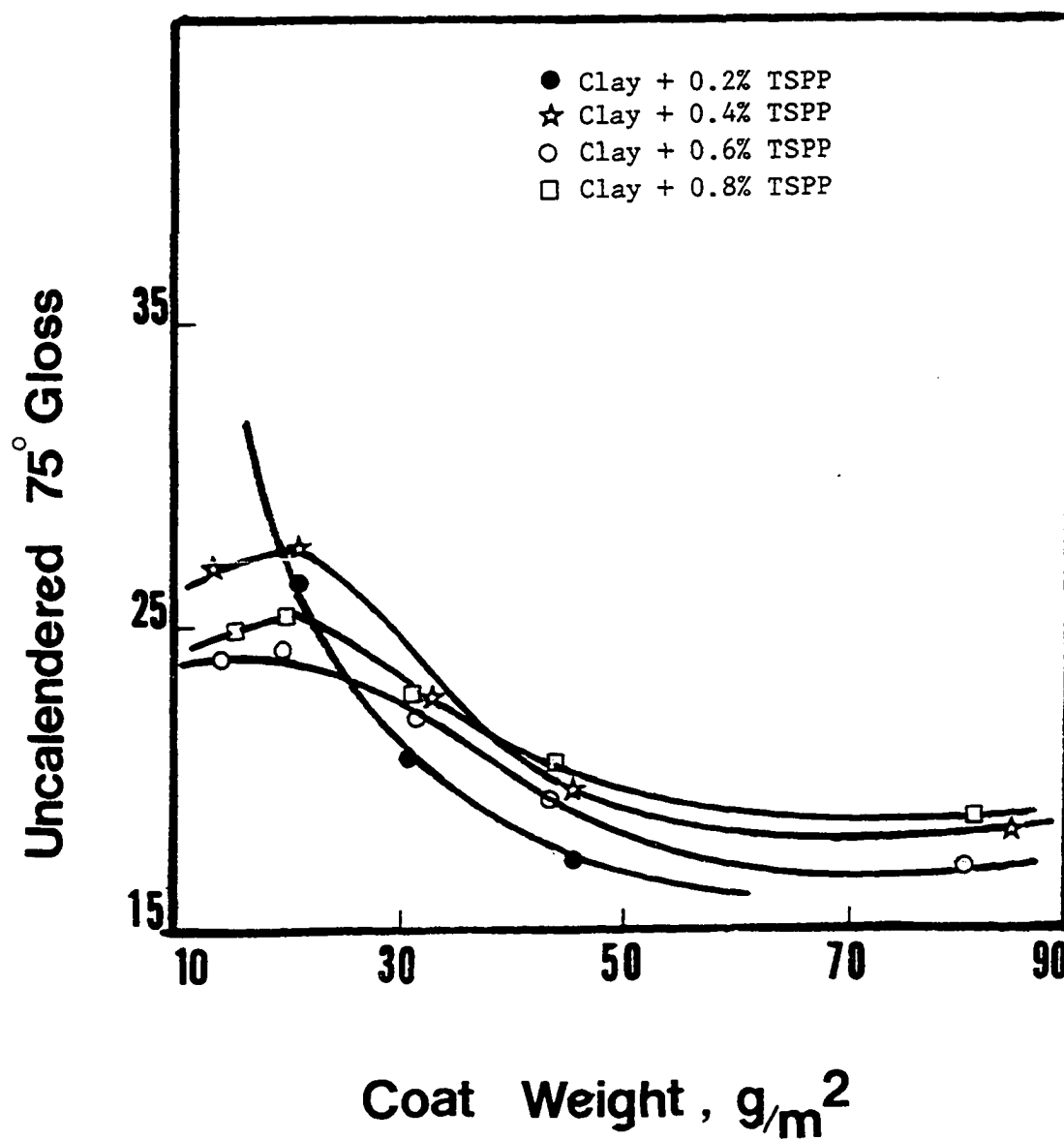
Relationship Between Time and Water Absorbed by Plastic Vellum Paper
(Cobb size test)

Effects of TSPP and Starch on Uncalendered,
75° Gloss of Coatings on Paper Substrate

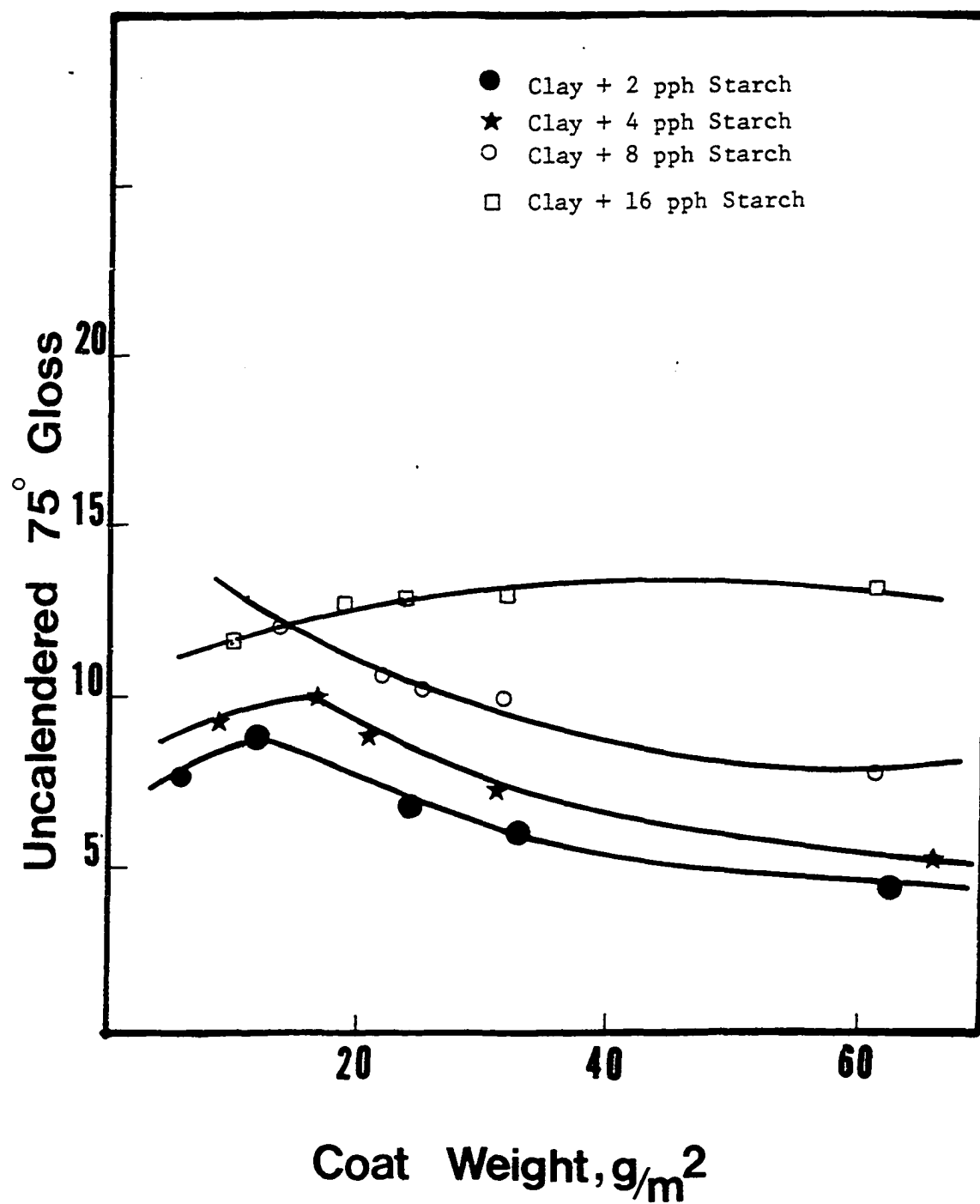
It was found that increasing amounts of TSPP in the clay dispersions produced dried coatings where the gloss increased slightly with increasing coat weight then decreased (Figure 36). It is possible that at low levels of relative pore volume (coat weights below 20 lb.) the pigment particles were packed more tightly together giving considerable specular reflection, but when the relative pore volume increased at higher coat weights, specular reflection and gloss decreased due to less tight packing.

When increasing levels of starch were added to the clay slip, the gloss vs. coat weight curves were shifted upward (Figure 37). As starch was added to the system, the pores were filled with starch which reduced the relative pore volume. At 8 and 16 pph starch gloss increased slightly with coat weight (rather than decreased as with lower levels of starch) indicating that starch had filled in the pores and the condition of pigment packing has little effect on gloss.

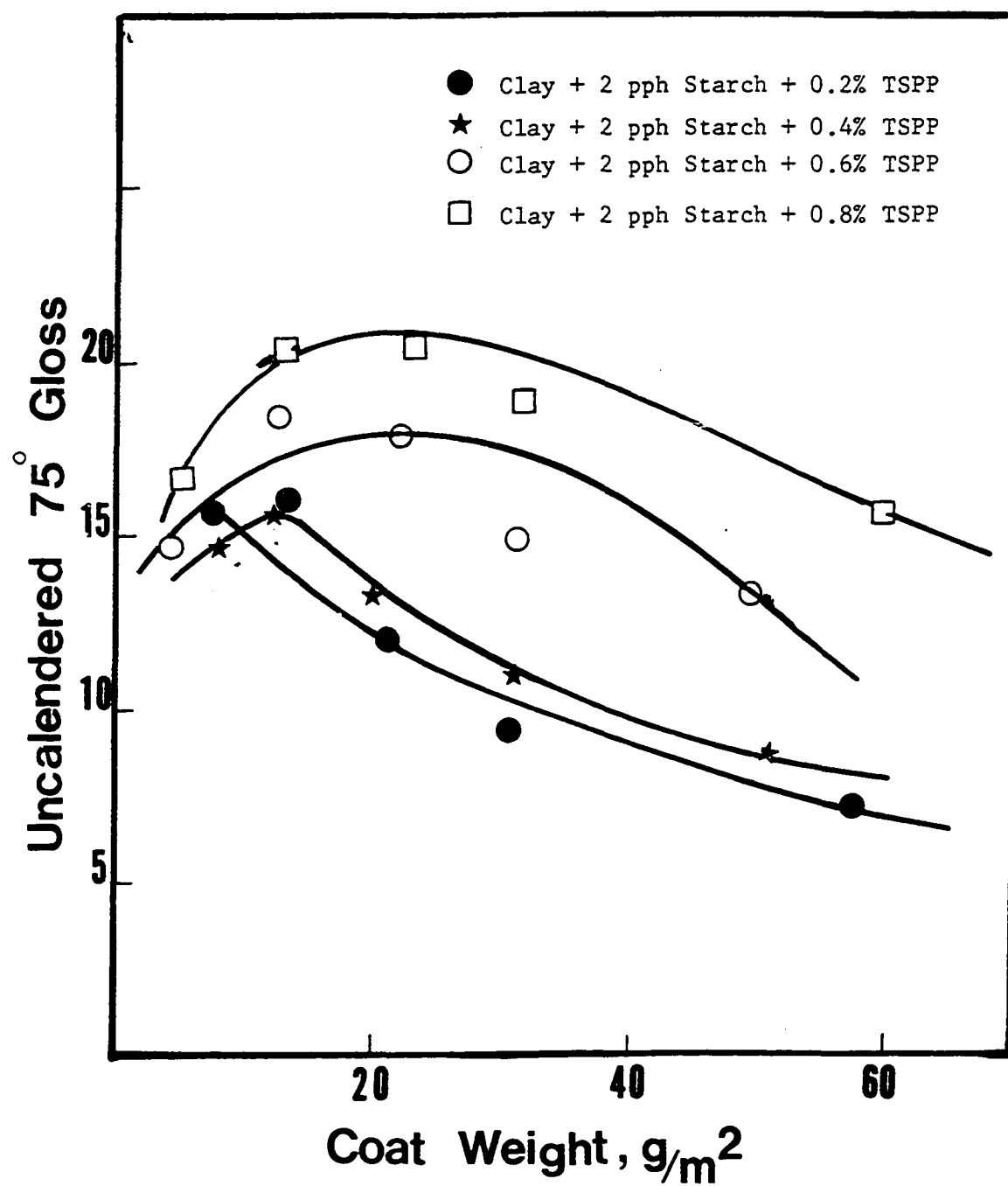
Figures 38-41 demonstrate a gloss dependence on coat weight similar to the other properties measured. Comparing these curves with the RPV data in Figures 23-26 it can be seen that the highest gloss correlates well with the lowest RPV, especially the 8 pph starch and 0.6% TSPP which gave the highest overall gloss and lowest RPV. While these data show good correlation between RPV and gloss, the correlation cannot be traced back to any outstanding viscosity or scattering characteristics.

**Fig.36**

Effect of Coat Weight on Uncalendered 75° Gloss with Paper Substrate

**Fig.37**

Effect of Coat Weight on Uncalendered 75° Gloss with Paper Substrate

**Fig.38**

Effect of Coat Weight on Uncalendered 75° Gloss with Paper Substrate

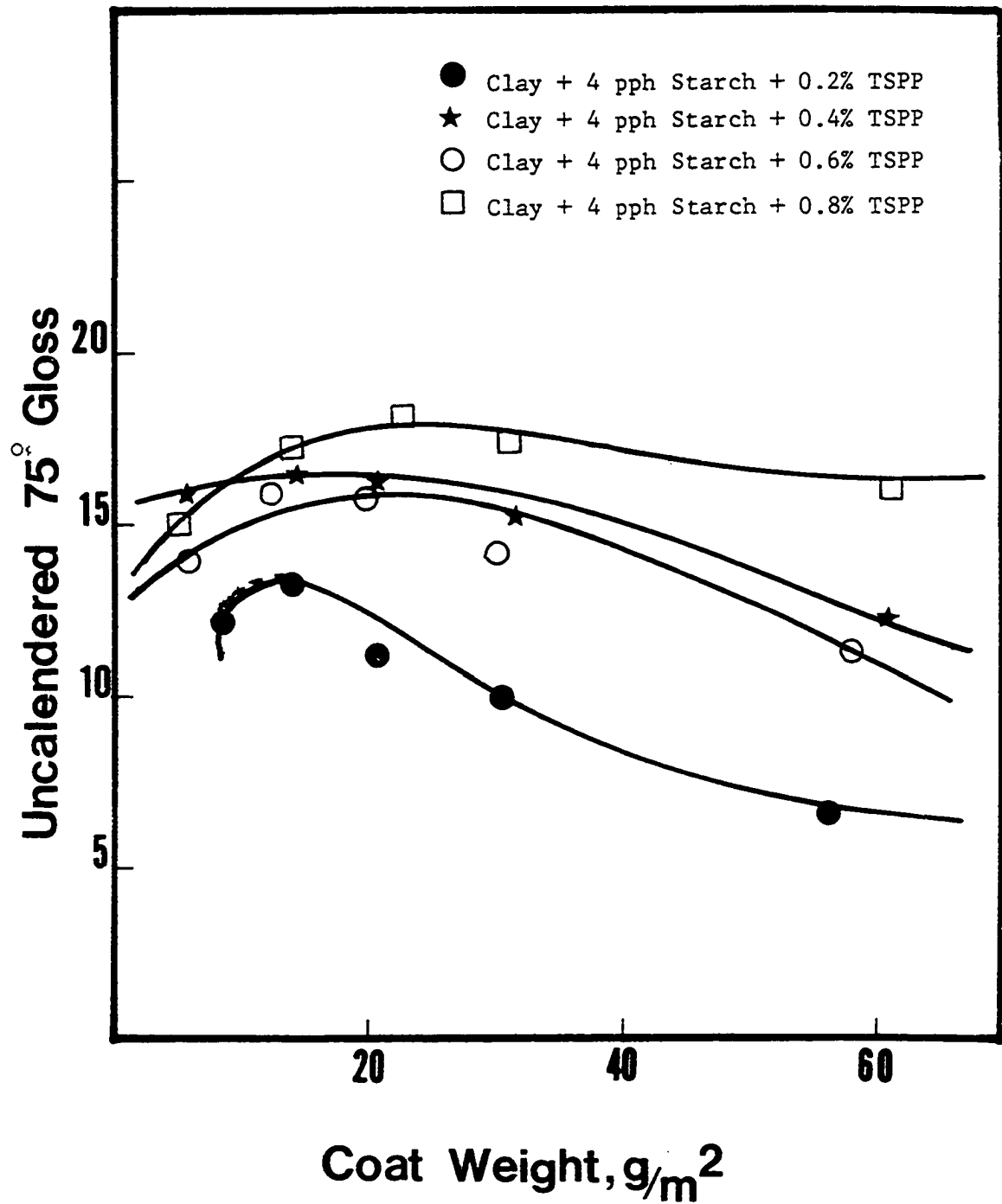


Fig.39

Effect of Coat Weight on Uncalendered 75° Gloss with Paper Substrate

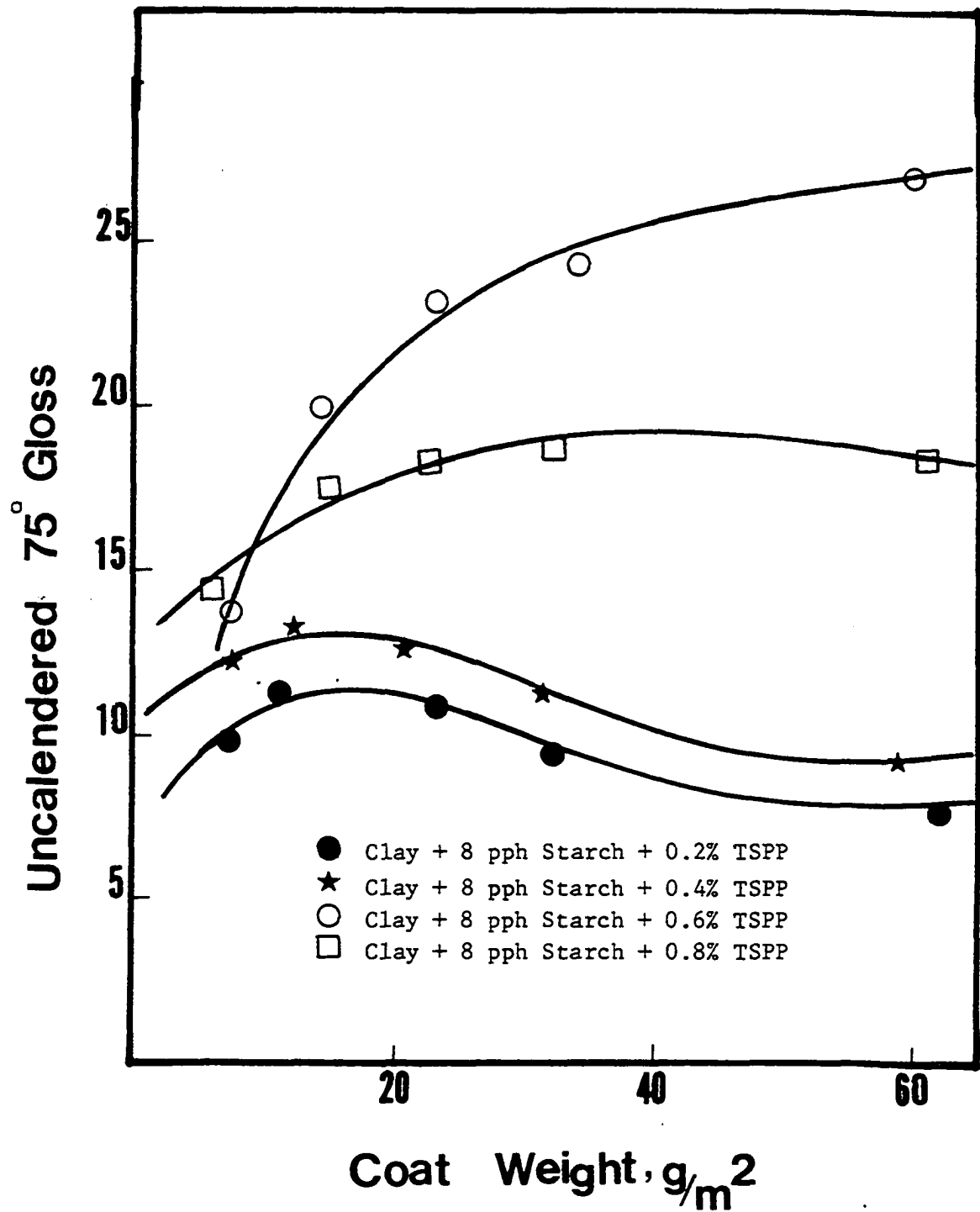
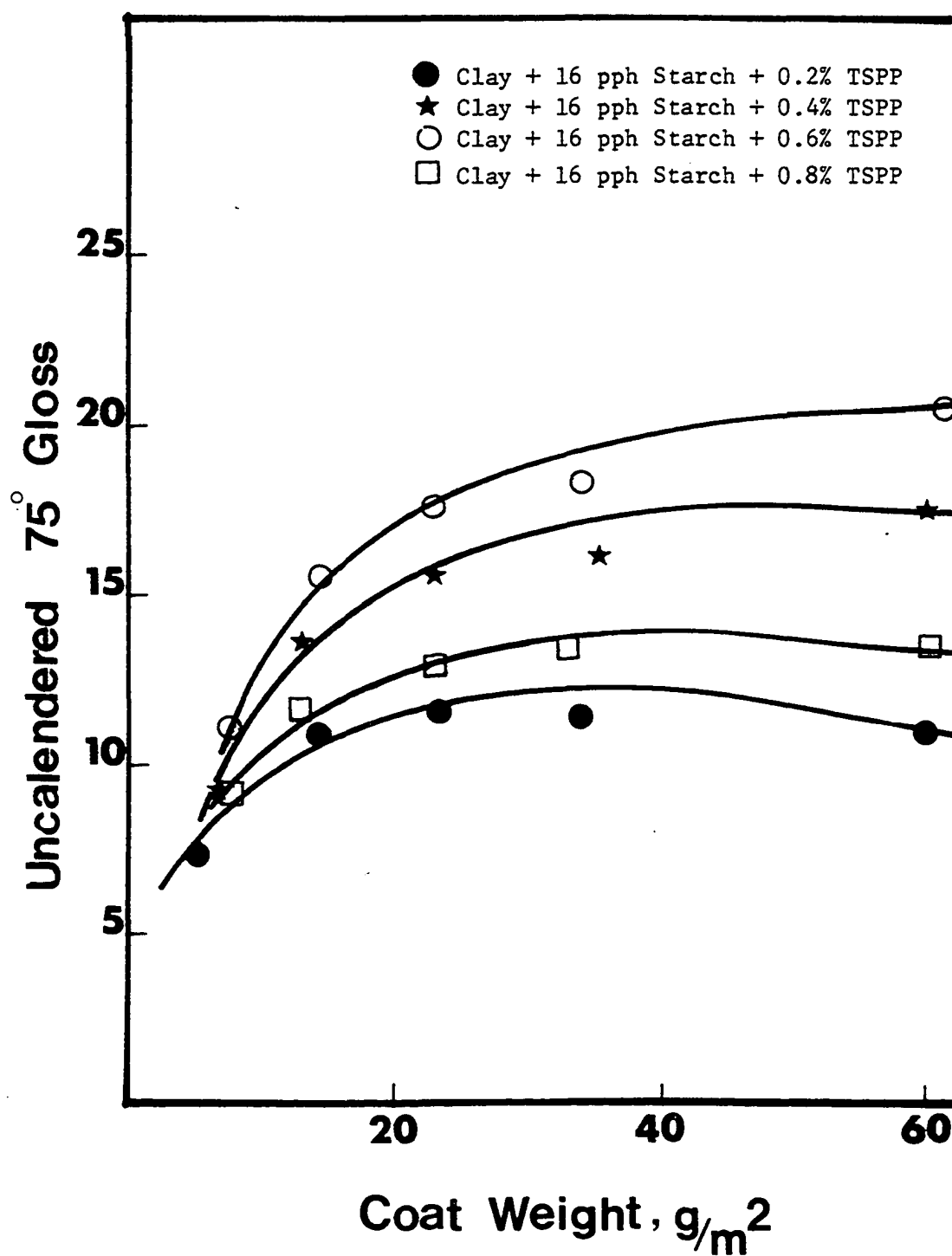


Fig.40

Effect of Coat Weight on Uncalendered 75° Gloss with Paper Substrate

**Fig.41**

Effect of Coat Weight on Uncalendered 75° Gloss with Paper Substrate

In order to eliminate the coat weight effect, values for gloss were obtained from the preceeding curves for all the coatings at 20 g/m^2 coat weight and plotted against the percentage TSPP (Figure 42), and pph starch (Figure 43). Figure 42 shows that increasing amounts of TSPP raised the gloss but different levels of starch did not have much effect in the gloss. Starch amount vs. gloss at different TSPP levels (Figure 43) indicated that gloss was very high at zero level of starch but at high levels of starch it decreased and then leveled off at about 3 pph starch.

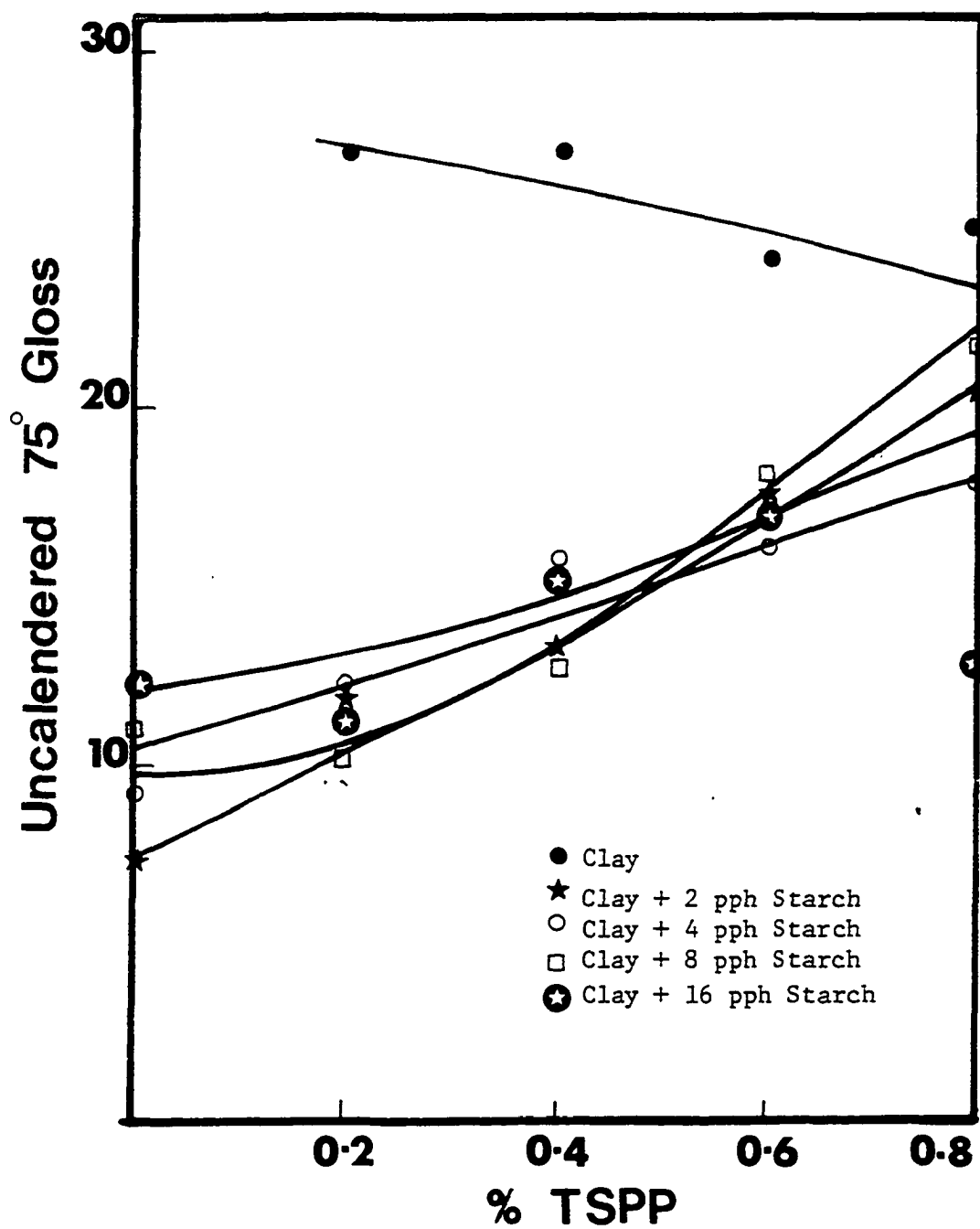


Fig.42

Effect of TSPP on Uncalendered 75° Gloss at Constant Coat Weight (20 g/m²) with Paper Substrate

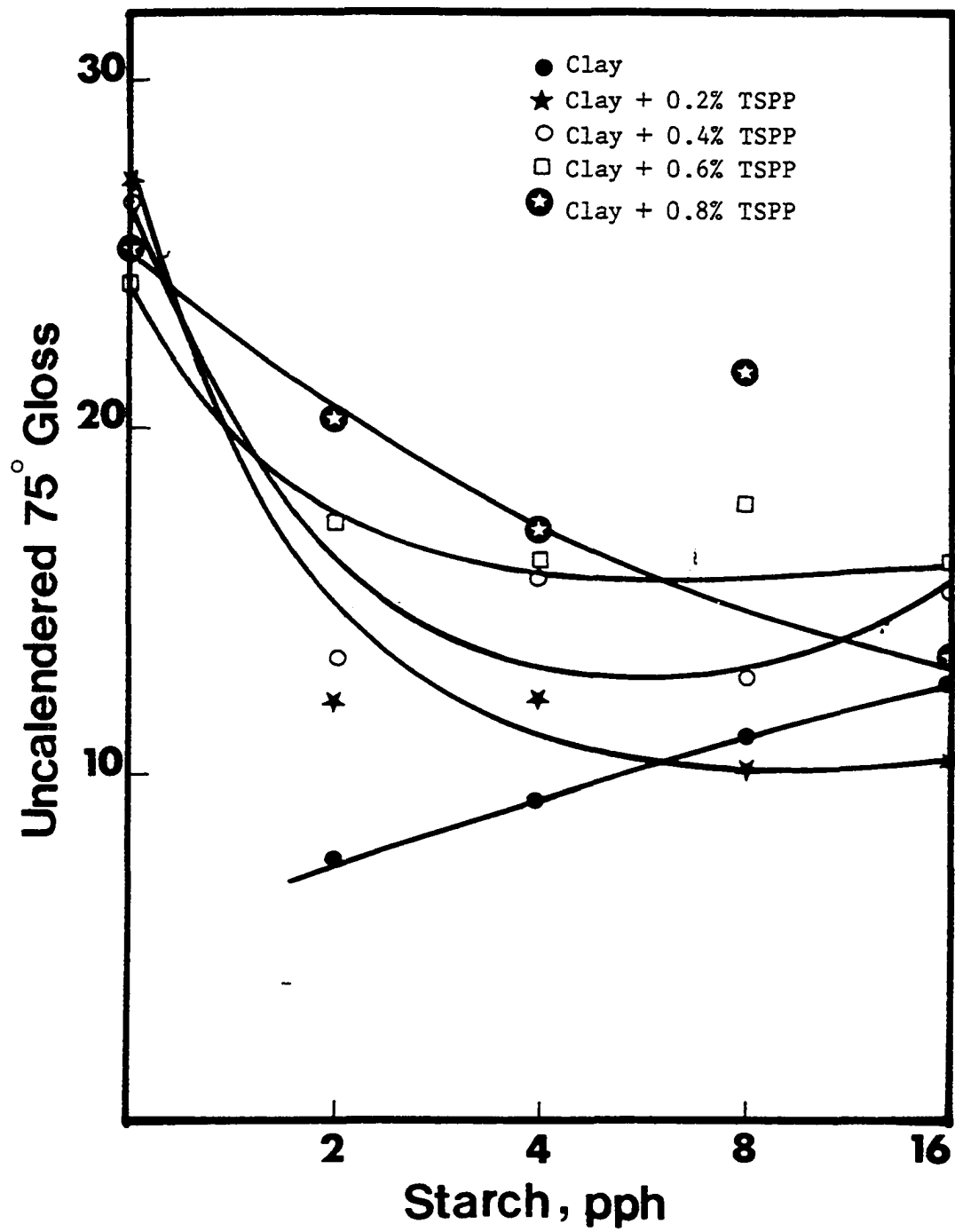


Fig.43

Effect of Starch on Uncalendered 75° Gloss at Constant Coat Weight (20 g/m²) with Paper Substrate

SUMMARY AND CONCLUSIONS

The relationships between the degree of clay dispersion in aqueous systems and optical and pore properties of dried starch-clay coatings were determined with the following conclusions.

Incremental addition of TSPP to clay slips, resulted in a decrease in Brookfield viscosity until a minimum at 0.13% TSPP was reached, then viscosity increased. The scattering coefficient of corresponding dried films also decreased to a minimum at about the same TSPP range (0.2%). Scattering coefficient then increased with increasing TSPP content for coatings applied on the paper but not for the black glass substrate.

By adding 2 pph starch to the clay slip, the scattering coefficient curve was shifted up and at higher levels of starch, the curve was shifted down. The above was true only for the paper but not the black glass substrate. This change in scattering coefficient was shown to correlate well with relative pore volume.

There was a disagreement between the two sets of scattering coefficients for the paper and black glass substrates. There are two possible explanations for the discrepancies obtained. First, the coating structure itself was different on the two substrates. Secondly, different methods of calculating scattering coefficient could have given different values. The data developed in this paper indicate that the former is most likely to have caused the difference.

It was also found that relative pore volume data on both substrates did not agree with each other, showing that coating structure was different on the two substrates leading to the different performance. It was also found that relative pore volume gave very good correlation with uncalendered 75° gloss, with high gloss at low pore volume.

In general, it can be concluded that the differences in pigment dispersion observed in an aqueous medium can be shown to effect packing structure, gloss, and scattering coefficient of the dried films. However, on absorptive substrates these dried film properties seem to be dependent on other factors such as adhesive migration and to vary with coat weight, likely due to differences in rate and mechanism of drying.

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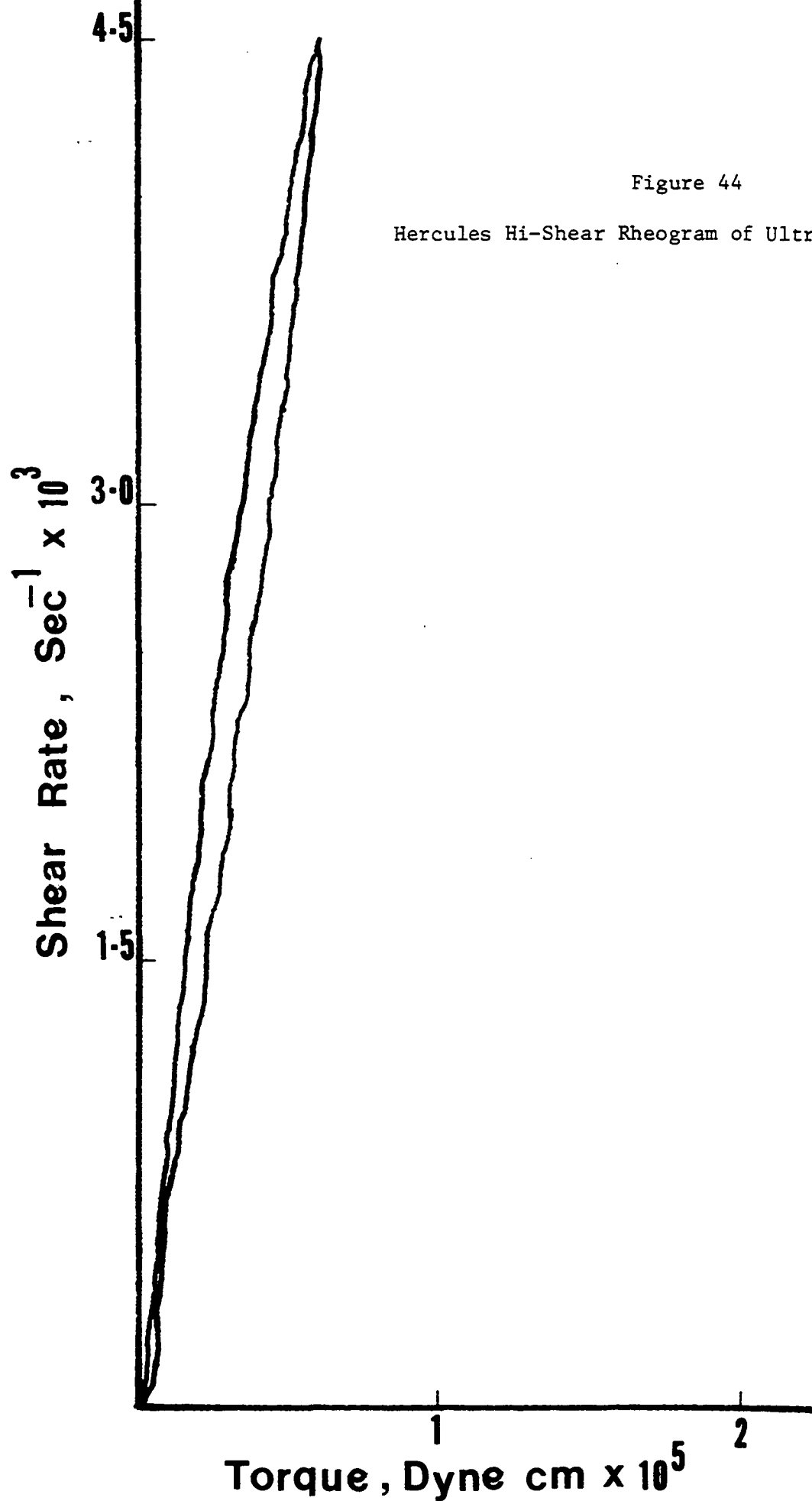
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APPENDIX I

PREPARATION OF PIGMENT

To satisfy the objectives of this project, it was necessary to start with a pigment which contained a minimum of deflocculating material in it. It is well known that all the available commercial products of the coating clays are predispersed with the TSPP during their processes, and therefore it was difficult to obtain clay which did not contain dispersing agent. Accordingly, clay was heated for different times at 450°F. to destroy the phosphate. Rheograms were made on the Hercules Hi-Shear Viscometer (Figures 44, 45) to monitor the process. It was found that at five hours, maximum flocculation was obtained for the slip. This showed that the effectiveness of TSPP was least after that time. Literature (29) does show that heating clay at 450°F. does not harm any properties of the clay.



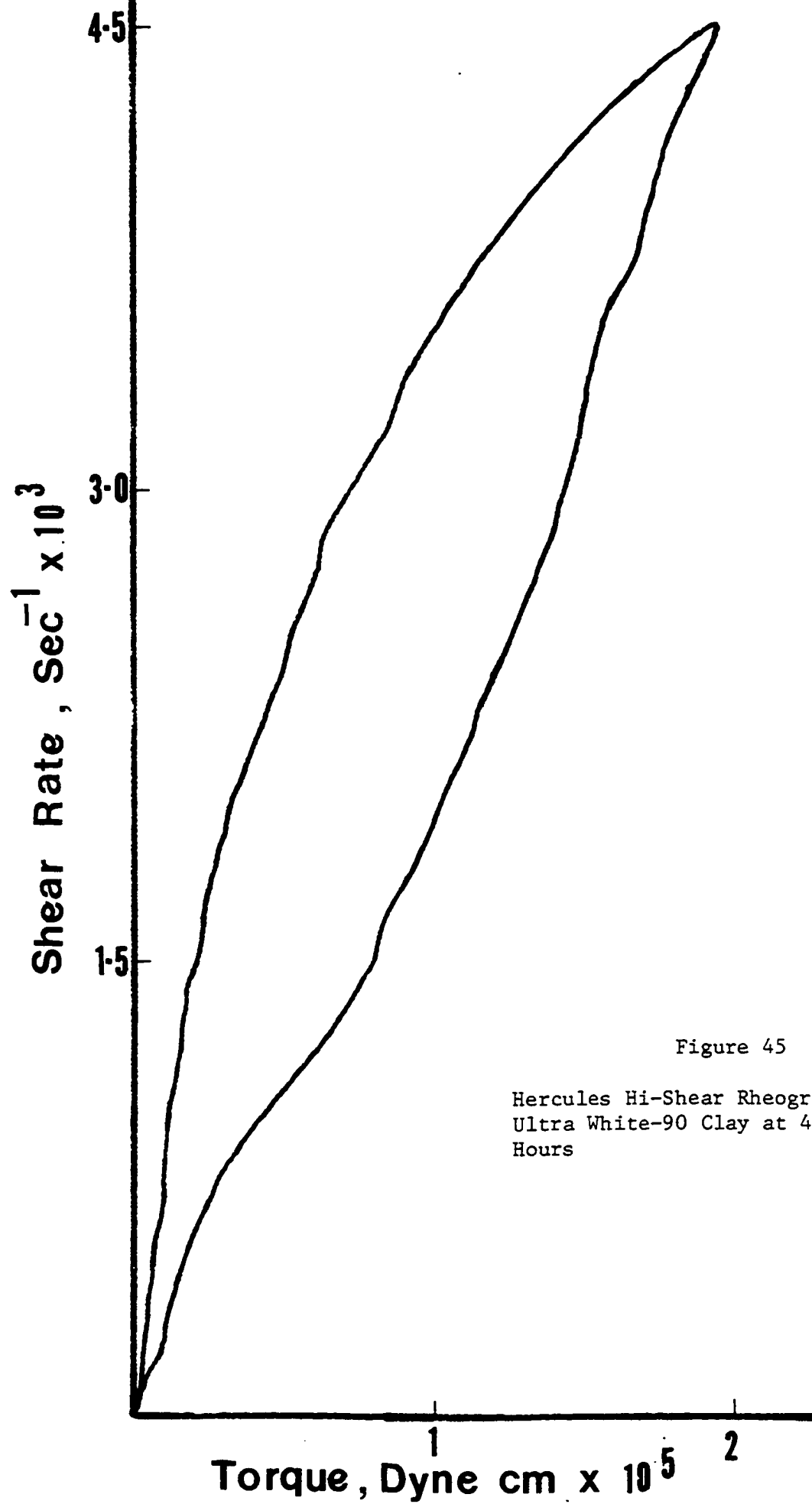


Figure 45

Hercules Hi-Shear Rheogram of Heated
Ultra White-90 Clay at 450°F. for Five
Hours

APPENDIX II

SAMPLE CALCULATION OF RELATIVE PORE VOLUME

Given the following coating formulation and data:

100 parts clay by weight
 4 parts starch by weight
 coat weight = 16.6 g/m²
 thickness = 0.32 x 10⁻³ in.

$$\begin{aligned}
 \text{Actual volume, (AV)} &= \text{Area} \times \text{thickness, (T)} \\
 &= (1 \times 10^4 \text{ cm}^2/\text{m}^2) (T \times 10^{-3} \text{ in.} \times 2.54 \text{ cm/in.}) \\
 &= T \text{ in} \times 25.4 \text{ cm}^3/\text{m}^2 \text{ in.} \\
 \text{AV} &= 0.32 \text{ in.} \times 25.4 \text{ cm}^3/\text{m}^2 \text{ in} \\
 &= 8.13 \text{ cm}^3/\text{m}^2
 \end{aligned}$$

$$\text{Relative Pore Volume (RPV)} = \frac{\text{Actual volume (AV)} - \text{Theoretical volume (TV)}}{\text{Theoretical volume (TV)}}$$

(a) By considering idealized void filling hypothesis

$$\text{TV} = \frac{\text{Total coat weight g/m}^2 \times \text{clay fraction}}{\text{clay density, g/cm}^3}$$

$$\begin{aligned}
 \text{TV} &= \frac{16.6 \text{ g/m}^2 \times (100/104)}{2.58 \text{ g/cm}^3} \\
 &= 6.18 \text{ cm}^3/\text{m}^2
 \end{aligned}$$

$$\text{RPV} = \frac{\text{AV} - \text{TV}}{\text{TV}}$$

$$\begin{aligned}
 \text{RPV} &= \frac{8.13 - 6.18}{6.18} \\
 &= 0.314
 \end{aligned}$$

(b) By not considering idealized void filling hypothesis

$$TV = \frac{\text{Total coat weight g/m}^2 \times \text{clay fraction}}{\text{clay density g/cm}^3} +$$

$$\frac{\text{Total coat weight g/m}^2 \times \text{starch fraction}}{\text{starch density g/cm}^3}$$

$$TV = \frac{16.6 \times (100/104)}{2.58} + \frac{16.6 (4/104)}{1.5}$$

$$= 6.61 \text{ cm}^3/\text{m}^2$$

$$RPV = \frac{AV - TV}{TV}$$

$$= \frac{8.13 - 6.61}{6.61}$$

$$= 0.230$$

APPENDIX III

TABLE I

BROOKFIELD VISCOSITY OF THE COATING
FORMULATIONS

No.	Clay Dry Parts	Starch Dry Parts	% TSPP ^a	Brookfield Viscosity in CPS			
				10 RPM	20 RPM	50 RPM	100 RPM
1	100			16,800	9,800	41,600	2,600
2	100		0.2	70	60	70	92
3	100		0.4	130	100	88	104
4	100		0.6	250	180	120	126
5	100		0.8	400	260	166	147
6	100	2		1,300	725	370	215
7	100	4		850	500	270	175
8	100	8		650	437	270	205
9	100	16		2,050	1,275	690	410
10	100	2	0.2	80	55	48	66
11	100	2	0.4	100	60	56	68
12	100	2	0.6	120	80	60	70
13	100	2	0.8	140	100	64	70
14	100	4	0.2	130	90	70	80
15	100	4	0.4	200	130	84	82
16	100	4	0.6	200	130	82	82
17	100	4	0.8	240	150	92	86
18	100	8	0.2	310	200	124	112
19	100	8	0.4	350	230	144	122

^a% based on clay.

TABLE I (Continued)

BROOKFIELD VISCOSITY OF THE COATING
FORMULATIONS

No.	Clay Dry Parts	Starch Dry Parts	% TSPP ^a	Brookfield Viscosity in CPS			
				10 RPM	20 RPM	50 RPM	100 RPM
20	100	8	0.6	400	250	144	114
21	100	8	0.8	420	265	156	122
22	100	16	0.2	750	487	300	215
23	100	16	0.4	800	500	290	205
24	100	16	0.6	800	500	290	210
25	100	16	0.8	875	562	320	222

^a% based on clay.

TABLE II
SCATTERING AND ABSORPTION COEFFICIENT
OF COATINGS ON PAPER SUBSTRATE

<u>No.</u>	<u>R₀</u>	<u>R_g</u>	<u>R</u>	<u>Coat Wt. g/m²</u>	<u>Scattering Coefficient</u>	<u>Absorption Coefficient</u>
1	0.8033	0.4140	0.7818	40.4583	0.1293	3.11 x 10 ⁻³
2	0.7933	0.4328	0.7150	20.5494	0.1156	3.1 x 10 ⁻³
			0.7398	30.7112	0.1006	2.71
			0.7442	45.5024	0.0715	1.92
			0.7472	82.0100	0.0412	1.10
			0.6810	11.4412	0.1514	4.07
3	0.7733	0.4052	0.7244	20.9257	0.1446	4.80 x 10 ⁻³
			0.7424	32.1040	0.1198	3.98
			0.7492	45.2390	0.0950	3.15
			0.7406	83.9672	0.0445	1.48
			0.6782	12.7587	0.1486	4.94
4	0.7675	0.4232	0.7256	19.2319	0.1636	5.76 x 10 ⁻³
			0.7444	31.5390	0.1330	4.68
			0.7514	43.7338	0.1108	3.90
			0.7522	80.1661	0.0616	2.17
			0.6910	14.2262	0.1498	5.27
5	0.7750	0.4180	0.7282	20.4365	0.1512	4.93 x 10 ⁻³
			0.7476	31.7277	0.1279	4.18
			0.7572	43.8091	0.1110	3.62
			0.7586	81.1445	0.0618	2.01
			0.7080	15.6942	0.1568	5.12
6	0.7733	0.3928	0.6970	11.9303	0.1926	6.40 x 10 ⁻³
			0.7430	23.9741	0.1635	5.43
			0.7534	32.8565	0.1427	4.74
			0.7616	62.4389	0.0910	3.02
			0.5894	5.8334	0.1585	5.26
7	0.7700	0.4320	0.7074	16.5973	0.1485	5.10 x 10 ⁻³
			0.7310	20.8128	0.1577	5.42
			0.7454	31.0122	0.1324	4.54
			0.7600	65.9770	0.0872	2.99
			0.6120	8.5809	0.1163	3.99

TABLE II (continued)

SCATTERING AND ABSORPTION COEFFICIENT
OF COATINGS ON PAPER SUBSTRATE

No.	<u>R₀₆</u>	<u>R_g</u>	<u>R</u>	<u>Coat Wt.</u> <u>g/m²</u>	<u>Scattering</u> <u>Coefficient</u>	<u>Absorption</u> <u>Coefficient</u>
8	0.7660	0.3865	0.6898	14.1133	0.1582	5.65 x 10 ⁻³
			0.7252	25.0282	0.1311	4.68
			0.7446	31.6900	0.1393	4.97
			0.7455	61.6863	0.0732	2.61
			0.7162	22.0174	0.1335	4.77
9	0.7433	0.3914	0.6534	18.5545	0.0934	4.14 x 10 ⁻³
			0.6930	24.4638	0.1062	4.71
			0.7188	32.7436	0.1138	5.04
			0.7292	61.1595	0.0755	3.34
			0.6256	10.9114	0.1238	5.48
10	0.7766	0.3812	0.6866	13.1350	0.1592	5.11 x 10 ⁻³
			0.7204	20.6999	0.1401	4.50
			0.7362	30.3725	0.1149	3.69
			0.7534	57.6214	0.0783	2.51
			0.6044	7.6778	0.1398	4.49
11	0.7733	0.3732	0.6880	12.7587	0.1698	5.64 x 10 ⁻³
			0.7242	19.4957	0.1595	5.30
			0.7328	31.2004	0.1106	3.67
			0.7484	50.9596	0.0850	2.82
			0.6072	7.8283	0.1438	4.78
12	0.7700	0.3759	0.6832	13.1350	0.1595	5.48 x 10 ⁻³
			0.7376	22.3932	0.1690	5.80
			0.7520	32.2921	0.1501	5.15
			0.7618	48.9276	0.1287	4.42
			0.5740	4.4431	0.1944	6.68
13	0.7800	0.3734	0.6972	12.8339	0.1786	5.54 x 10 ⁻³
			0.7402	22.5442	0.1596	4.95
			0.7594	31.9534	0.1514	4.69
			0.7694	59.8796	0.1022	3.17
			0.5854	4.9680	0.1889	5.86

TABLE II (Continued)

SCATTERING AND ABSORPTION COEFFICIENT
OF COATINGS ON PAPER SUBSTRATE

No.	<u>R_s</u>	<u>R_g</u>	<u>R</u>	Coat Wt. <u>g/m²</u>	Scattering Coefficient	Absorption Coefficient
14	0.7766	0.3710	0.6850	13.9252	0.1501	4.82 x 10 ⁻³
			0.7208	20.5870	0.1428	4.59
			0.7358	30.3725	0.1152	3.70
			0.7518	55.8147	0.0791	2.54
			0.6082	8.5056	0.1333	4.28
15	0.7766	0.3734	0.6928	14.5272	0.1537	4.93 x 10 ⁻³
			0.7334	20.6999	0.1638	5.26
			0.7470	31.7653	0.1285	4.12
			0.7690	60.9714	0.1092	3.51
			0.5900	5.9463	0.1645	5.28
16	0.7733	0.3718	0.6866	12.8339	0.1670	5.55 x 10 ⁻³
			0.7248	19.6463	0.1596	5.30
			0.7514	30.5230	0.1498	4.97
			0.7626	57.9977	0.1019	3.38
			0.5834	5.8334	0.1608	5.34
17	0.7733	0.3710	0.6898	13.9628	0.1581	5.25 x 10 ⁻³
			0.7362	23.1086	0.1564	5.19
			0.7548	31.0498	0.1574	5.23
			0.7634	61.0842	0.0992	3.29
			0.5770	5.7958	0.1542	5.12
18	0.7700	0.3731	0.6630	11.2906	0.1566	5.38 x 10 ⁻³
			0.7360	23.2592	0.1593	5.47
			0.7434	32.2168	0.1286	4.42
			0.7532	62.5894	0.0795	2.73
			0.5888	7.3391	0.1336	4.59
19	0.7675	0.3715	0.6674	12.7210	0.1435	5.13 x 10 ⁻³
			0.7060	20.9257	0.1265	4.45
			0.7356	31.8405	0.1186	4.17
			0.7560	59.2023	0.0948	3.34
			0.5706	7.6401	0.1120	3.94

TABLE II (Continued)

SCATTERING AND ABSORPTION COEFFICIENT
OF COATINGS ON PAPER SUBSTRATE

No.	R_{90}	R_g	R	Coat Wt. g/m ²	Scattering Coefficient	Absorption Coefficient
20	0.7700	0.3754	0.6864	14.5649	0.1481	5.09 x 10 ⁻³
			0.7276	22.9581	0.1442	4.95
			0.7558	33.8725	0.1559	5.35
			0.7662	59.7667	0.1295	4.44
			0.5910	7.3767	0.1344	4.62
21	0.7675	0.3710	0.6892	15.2803	0.1572	5.18 x 10 ⁻³
			0.7280	22.5818	0.1508	5.31
			0.7468	31.9911	0.1422	5.00
			0.7590	61.2348	0.1007	3.54
			0.5810	5.9087	0.1577	5.55
22	0.7550	0.3767	0.6288	14.0004	0.0989	3.93 x 10 ⁻³
			0.6882	22.9957	0.1019	4.05
			0.7092	33.7596	0.0873	3.47
			0.7256	59.3904	0.0619	2.46
			0.5264	5.2690	0.2576	1.02 x 10 ⁻²
23	0.7550	0.3746	0.6324	13.7747	0.1039	4.13 x 10 ⁻³
			0.6868	22.8076	0.1016	4.04
			0.7152	35.1524	0.0905	3.60
			0.7372	60.3312	0.0751	2.98
			0.5362	6.3979	0.1004	3.99
24	0.7550	0.3813	0.6410	14.4896	0.1048	4.16 x 10 ⁻³
			0.6886	23.2968	0.1005	3.99
			0.7276	33.8725	0.1117	4.44
			0.7326	61.5734	0.0669	2.66
			0.5684	8.0164	0.1039	4.12
25	0.7500	0.3808	0.6136	12.8339	0.0955	3.98 x 10 ⁻³
			0.6718	23.1839	0.0878	3.65
			0.7004	33.3457	0.0821	3.42
			0.7166	60.5569	0.0557	2.32
			0.5384	8.7690	0.0734	3.06

TABLE III
SCATTERING COEFFICIENT OF COATINGS
ON BLACK GLASS SUBSTRATE

No.	Coating Formulations	Brightness R_o	Coat Wt. g/m^2	Scattering Coefficient
1	100 parts clay			
2	100 parts clay	0.6430	10.2297	0.1760
	0.2% TSPP	0.6770	24.7487	0.0846
		0.7400	43.1591	0.0659
3	100 parts clay	0.6773	18.9103	0.1109
	0.4% TSPP	0.7206	36.3736	0.0709
		0.7273	46.0526	0.0579
4	100 parts clay	0.5913	9.3862	0.1541
	0.6% TSPP	0.7240	33.7074	0.0778
		0.7306	53.0795	0.0510
5	100 parts clay	0.6940	23.0778	0.0982
	0.8% TSPP	0.7154	34.1521	0.0736
		0.7258	34.1521	0.0775
6	100 parts clay	0.6828	17.0156	0.1265
	2 parts Starch	0.7318	37.9598	0.0718
		0.7440	55.6803	0.0521
7	100 parts clay	0.7016	22.7680	0.1032
	4 parts Starch	0.7324	38.6988	0.0707
		0.7418	55.8523	0.0514
8	100 parts clay	0.6946	22.7162	0.1001
	8 parts Starch	0.7290	40.5070	0.0664
		0.7400	65.8245	0.0432
9	100 parts clay	0.6524	22.7509	0.0824
	16 parts Starch	0.6824	27.8831	0.0770
		0.7156	65.2562	0.0385
10	100 parts clay	0.6860	19.3061	0.1131
	2 parts Starch	0.7110	38.4921	0.0639
	0.2% TSPP	0.7400	60.6229	0.0469

TABLE III (Continued)

SCATTERING COEFFICIENT OF COATINGS
ON BLACK GLASS SUBSTRATE

No.	Coating Formulations	Brightness R_o	Coat Wt. g/m^2	Scattering Coefficient
11	100 parts clay	0.7050	21.0630	0.1134
	2 parts starch	0.7248	30.9316	0.0851
	0.4% TSPP	0.7368	68.1839	0.0410
12	100 parts clay	0.6780	16.8778	0.1247
	2 parts starch	0.7200	29.5882	0.0869
	0.6% TSPP	0.7423	70.4744	0.0408
13	100 parts clay	0.7144	28.0381	0.0892
	2 parts starch	0.7292	30.3456	0.0887
	0.8% TSPP	0.7490	60.7607	0.0491
14	100 parts clay	0.6738	19.0134	0.1086
	4 parts starch	0.7252	43.3663	0.0608
	0.2% TSPP	0.7402	60.8985	0.0467
15	100 parts clay	0.7164	27.5557	0.0916
	4 parts starch	0.7220	29.4675	0.0881
	0.4% TSPP	0.7476	65.4453	0.0452
16	100 parts clay	0.7150	23.5255	0.1066
	4 parts starch	0.7362	38.3543	0.0727
	0.6% TSPP	0.7466	61.9492	0.0475
17	100 parts clay	0.7192	22.4406	0.1141
	4 parts starch	0.7400	38.0616	0.0747
	0.8% TSPP	0.7488	63.7061	0.0467
18	100 parts clay	0.6444	15.9132	0.1138
	8 parts starch	0.7208	36.7529	0.0702
	0.2% TSPP	0.7350	61.7083	0.0449
19	100 parts clay	0.6914	29.8045	0.1076
	8 parts starch	0.7164	37.6139	0.0671
	0.4% TSPP	0.7324	62.4658	0.0438
20	100 parts clay	0.7152	22.1308	0.1134
	8 parts starch	0.7260	30.1394	0.0879
	0.6% TSPP	0.7494	68.1839	0.0438

TABLE III (Continued)
SCATTERING COEFFICIENT OF COATINGS
ON BLACK GLASS SUBSTRATE

No.	Coating Formulations	Brightness R_o	Coat Wt. g/m^2	Scattering Coefficient
21	100 parts clay	0.7066	21.8033	0.1104
	8 parts starch	0.7306	39.5428	0.0685
	0.8% TSPP	0.7430	63.7921	0.0453
22	100 parts clay	0.5746	15.3966	0.0877
	16 parts starch	0.6842	37.3036	0.0580
	0.2% TSPP	0.7134	61.2260	0.0406
23	100 parts clay	0.6546	22.3717	0.0847
	16 parts starch	0.6956	38.5439	0.0592
	0.4% TSPP	0.7182	55.7321	0.457
24	100 parts clay	0.6016	17.0499	0.0885
	16 parts starch	0.7004	38.1647	0.0612
	0.6% TSPP	0.7242	63.0859	0.0416
25	100 parts clay	0.6362	22.3888	0.0781
	16 parts starch	0.6684	38.0787	0.0529
	0.8% TSPP	0.6994	55.3011	0.0420

TABLE IV
RELATIVE PORE VOLUME OF COATINGS
ON PAPER SUBSTRATE

No.	Thickness in.	Coat Wt. g/m ²	Theoretical Volume	Actual Volume	Pore Volume	Relative Pore Volume
1	1.26	40.4583	15.6815	32.0040	16.3225	
2	0.36	20.5494	7.9648	9.1440	1.1792	0.1480
	0.95	30.7112	11.9035	24.1300	12.2265	1.0271
	1.51	45.5024	17.6365	38.3540	20.7175	1.1746
	2.85	82.0100	31.7868	72.3900	40.6032	1.2773
	0.14	11.4412	4.4345			
3	0.38	20.9257	8.1107	9.6520	1.5413	0.1900
	0.87	32.1040	12.4434	22.0980	9.6546	0.7758
	1.57	45.2390	17.5344	39.8780	22.3436	1.2742
	2.94	83.9672	32.5454	74.6760	42.1306	1.2945
	0.01	12.7587	4.9452			
4	0.36	19.2319	7.4542	9.1440	1.6898	0.2260
	0.82	31.5390	12.2224	20.8280	8.6056	0.7040
	1.40	43.7338	16.9510	35.5600	18.6090	1.0978
	2.79	80.1661	31.0721	70.8660	39.7939	1.2806
	0.05	14.2262	5.5140			
5	0.28	20.4365	7.9211	7.1120		
	0.79	31.7277	12.2975	20.0660	7.7685	0.6317
	1.42	43.8091	16.9802	36.0680	19.0878	1.1241
	2.75	81.1445	31.4513	69.8500	38.3987	1.2208
	0.09	15.6942	6.0830	2.2860		
6	0.43	11.9303	4.6888	10.9220	6.2332	1.3293
	1.41	23.9741	9.4224	35.8140	26.3916	2.8009
	1.90	32.8565	12.9142	48.2600	35.3458	2.7369
	3.13	62.4389	24.5401	79.5020	54.9619	2.2396
	0.04	5.8334	2.2926	1.0160		
7	0.32	16.5973	6.6101	8.1280	1.5179	0.2296
	0.79	20.8128	8.2891	20.0660	11.7769	1.4207
	1.48	31.0122	12.3512	37.5920	25.2408	2.0435
	3.06	65.9770	26.2769	77.7240	51.4471	1.9578
	0.09	8.5809	3.4174	2.2860		

TABLE IV (Continued)

RELATIVE PORE VOLUME OF COATINGS
ON PAPER SUBSTRATE

No.	Thickness in.	Coat Wt. g/m ²	Theoretical Volume	Actual Volume	Pore Volume	Relative Pore Volume
8	0.52	14.1133	5.7611	13.2080	7.4469	1.2926
	1.23	25.0282	10.2166	31.2420	21.0254	2.0579
	1.83	31.6900	12.9360	46.4820	33.5460	2.5932
	3.00	61.6863	25.1815	76.2000	51.0185	2.0260
	0.84	22.0174	8.9876	21.3360	12.3484	1.3739
9	0.66	18.5545	7.9048	16.7640	8.8592	1.1207
	1.26	24.4638	10.4225	32.0040	21.5815	2.0706
	1.85	32.7436	13.9500	46.9900	33.0400	2.3684
	2.94	61.1595	26.0563	74.6760	48.6197	1.8659
	0.20	10.9114	4.6485	5.0800	0.4315	0.0928
10	0.37	13.1350	5.1623	9.3980	4.2357	0.8205
	0.97	20.6999	8.1355	24.6380	16.5025	2.0284
	1.54	30.3725	11.9371	39.1160	27.1789	2.2768
	2.84	57.6214	22.6466	72.1360	49.4894	2.1852
	0.08	7.6778	3.0174	2.0320		
11	0.36	12.7587	5.0143	9.1440	4.1297	0.8235
	1.03	19.4957	7.6622	26.1620	18.4998	2.4144
	1.62	31.2004	12.2625	41.1480	28.8855	2.3555
	2.70	50.9596	20.0284	68.5800	48.5516	2.4241
	0.14	7.8283	3.0766	3.5560	0.4794	0.1558
12	0.30	13.1350	5.1623	7.6200	2.4577	0.4760
	0.89	22.3932	8.8011	22.6060	13.8049	1.5685
	1.53	32.2921	12.6916	38.8620	26.1704	2.0620
	2.57	48.9276	19.2297	65.2780	46.0483	2.3946
	0.01	4.4431	1.7461			
13	0.23	12.8339	5.0439	5.8420	0.7981	0.1582
	0.72	22.5442	8.8603	18.2880	9.4277	1.0640
	1.31	31.9534	12.5584	33.2740	20.7156	1.6495
	2.53	59.8796	23.5342	64.2620	40.7278	1.7305
	0.06	4.9680	1.9524	1.5240		

TABLE IV (Continued)

RELATIVE PORE VOLUME OF COATINGS
ON PAPER SUBSTRATE

No.	Thickness in.	Coat Wt. g/m ²	Theoretical Volume	Actual Volume	Pore Volume	Relative Pore Volume
14	0.47	13.9252	5.5459	11.9380	6.3921	1.1525
	0.94	20.5870	8.1992	23.8760	15.6768	1.9119
	1.76	30.3725	12.0965	44.7040	32.6075	2.6956
	2.92	55.8197	22.2314	74.1680	51.9366	2.3361
	0.03	8.5056	3.3875			
15	0.34	14.5272	5.7857	8.6360	2.8503	0.4926
	0.91	20.6999	8.2441	23.1140	14.8699	1.8037
	1.57	31.7653	12.6512	39.8780	27.2268	2.1521
	2.78	60.9714	24.2832	70.6120	46.3288	1.9078
	0.04	5.9463	2.3682	1.0160		
16	0.29	12.8339	6.1113	7.3660	1.2547	0.2053
	0.85	19.6463	7.8245	21.5900	13.7655	1.7592
	1.53	30.5230	12.1564	38.8620	26.7056	2.1968
	2.77	57.9977	23.0989	70.3580	47.2591	2.0459
	0.12	5.8334	2.3232	3.0480	0.7248	0.3119
17	0.28	13.9628	5.5609	7.1120	1.5511	0.2789
	0.83	23.1086	9.2034	21.0820	11.8786	1.2906
	1.40	31.0498	12.3662	35.5600	23.1938	1.8755
	2.64	61.0842	24.3281	67.0560	42.7279	1.7563
	0.05	5.7958	2.3082	1.2700		
18	0.35	11.2906	4.6088	8.8900	4.2812	0.9289
	1.14	23.2592	9.4945	28.9560	19.4615	2.0497
	1.79	32.2168	13.1511	45.4660	32.3149	2.4572
	3.10	62.5894	25.5495	78.7400	53.1905	2.0818
	0.13	7.3391	2.9957	3.3020	0.3063	0.1022
19	0.35	12.7210	5.1927	8.8900	3.6973	0.7120
	0.94	20.9257	8.5420	23.8760	15.3340	1.7951
	1.70	31.8405	12.9974	43.1800	30.1826	2.3222
	2.93	59.2023	24.1668	74.4220	50.2552	2.0795
	0.07	7.6401	3.1186	1.7780		

TABLE IV (Continued)

RELATIVE PORE VOLUME OF COATINGS
ON PAPER SUBSTRATE

No.	Thickness in.	Coat Wt. g/m ²	Theoretical Volume	Actual Volume	Pore Volume	Relative Pore Volume
20	0.17	14.5649	5.9454	4.3180		
	0.58	22.9581	9.3716	14.7320	5.3604	0.5719
	1.01	33.8725	13.8270	25.6540	11.8270	0.8553
	1.91	59.7667	24.3971	48.5140	24.1169	0.9885
	0.10	7.3767	3.0110	2.5400		
21	0.40	15.2803	6.2375	10.1600	3.9225	0.6288
	0.92	22.5818	9.2180	23.3680	14.1500	1.5350
	1.55	31.9911	13.0590	39.3700	26.3110	2.0147
	2.52	61.2348	24.9964	64.0080	39.0116	1.5606
	0.09	5.9087	2.4118	2.2860		
22	0.26	14.004	5.9662	6.6040	0.6378	0.1069
	0.90	22.9957	9.7970	22.8600	13.0630	1.3333
	1.63	33.7596	14.3829	41.4020	27.0191	1.8785
	2.65	59.3904	25.3027	67.3100	42.0073	1.6601
	0.01	5.2690	2.2446			
23	0.24	13.7747	5.8685	6.0960	0.2275	0.0387
	0.89	22.8076	9.7168	22.6060	12.8892	1.3264
	1.51	35.1524	14.9762	38.3540	23.3778	1.5609
	2.31	60.3312	25.7035	58.6740	32.9705	1.2827
	0.04	6.3979	2.7256			
24	0.25	14.4896	6.1730	6.3500	0.1770	0.0286
	0.75	23.2968	9.9253	19.0500	9.1247	0.9193
	1.20	33.8725	14.4310	30.4800	16.0490	1.1121
	1.94	61.5734	26.2327	49.2760	23.0433	0.8784
	0.09	8.0164	3.4152			
25	0.30	12.8339	5.4677	7.6200	2.1523	0.3936
	1.02	23.1839	9.8772	25.9080	16.0308	1.6230
	1.61	33.3457	14.2065	40.8940	26.6875	1.8785
	2.47	60.5569	25.7996	62.7380	36.9384	1.4317
	0.15	8.7690	3.7358	3.8100	0.0742	0.0198

TABLE V
RELATIVE PORE VOLUME OF COATINGS
ON BLACK GLASS SUBSTRATE

No.	Thickness in.	Coat Wt. g/m ²	Theoretical Volume	Actual Volume	Pore Volume	Relative Pore Volume
1						
2	0.75	10.2297	3.9650	19.0500	15.0850	3.8045
	1.05	24.7487	9.5925	26.6700	17.0775	1.7802
	2.40	88.6444	34.3582	60.9600	26.6018	0.7742
3	1.05	18.9103	7.3295	26.6700	19.3405	2.6387
	1.20	36.3736	14.0982	30.4800	16.3818	1.1619
	1.80	46.0526	17.8498	45.7200	27.8702	1.5613
4	1.17	9.3862	3.6380	29.7180	26.0800	7.1687
	1.40	33.7044	13.0637	35.5600	22.4963	1.7220
	2.00	53.0795	20.5734	50.8000	30.2266	1.4692
5	0.65	23.0778	8.9448	16.5100	7.5692	0.8457
	1.50	34.1521	13.2372	38.1000	24.8628	1.8782
	1.40	34.1521	13.2372	35.5600	22.3228	1.6863
6	0.65	17.0156	6.6875	16.5100	9.8225	1.4687
	1.50	37.9598	14.9192	38.1000	23.1808	1.5537
	2.00	55.6803	21.8838	50.8000	28.9162	1.3213
7	1.30	22.7680	9.0678	33.0200	23.9522	2.6414
	1.80	38.6988	15.4126	45.7200	30.3074	1.9652
	2.30	55.8523	22.2444	58.4200	36.1576	1.6262
8	1.20	22.7162	9.2728	30.4800	21.2072	2.2870
	1.60	40.5070	16.5352	40.6400	24.1048	1.4577
	2.30	65.8245	26.8701	58.4200	31.5499	1.1741
9	1.00	22.7509	9.6927	25.4000	15.7073	1.6205
	1.10	27.8831	11.8792	27.9400	16.0608	1.3520
	1.75	65.2562	27.8018	44.4500	16.6482	0.5988
10	0.65	19.3061	7.5877	16.5100	8.9223	1.1758
	1.50	38.4921	15.1284	38.1000	22.9716	1.5184
	1.90	60.6229	23.8264	48.2600	24.4336	1.0254

TABLE V (Continued)

RELATIVE PORE VOLUME OF COATINGS
ON BLACK GLASS SUBSTRATE

No.	Thickness in	Coat Wt. g/m ²	Theoretical Volume	Actual Volume	Pore Volume	Relative Pore Volume
11	1.07	21.0630	8.2783	27.1780	18.8997	2.2830
	1.37	30.9316	12.1568	34.7980	22.6412	1.8624
	2.50	68.1839	26.7981	63.5000	36.7019	1.3695
12	0.62	16.8778	6.6334	15.7480	9.1146	1.3740
	1.20	29.5882	11.6289	30.4800	18.8511	1.6210
	2.50	70.4744	27.6983	63.5000	35.8017	1.2925
13	1.00	28.0381	11.0196	25.4000	14.3804	1.3049
	1.05	30.3456	11.9265	26.6700	14.7435	1.2361
	1.90	60.7607	23.8806	48.2600	24.3794	1.0208
14	0.75	19.0134	7.5724	19.0500	11.4776	1.5157
	1.17	43.3663	17.2715	29.7180	12.4465	0.7206
	2.16	60.8985	24.2211	53.3400	29.1189	1.2022
15	0.80	27.5557	10.9747	20.3200	9.3453	0.8515
	1.17	29.4675	11.7360	29.7180	17.9820	1.5322
	2.37	65.4453	26.0650	60.1980	34.1330	1.3095
16	1.00	23.5255	9.3695	25.4000	16.0305	1.7109
	1.57	38.3543	15.2754	39.8780	24.6026	1.6106
	2.37	61.9492	24.6726	60.1980	35.5254	1.4398
17	1.00	22.4406	8.9347	25.4000	16.4626	1.8419
	1.75	38.0616	15.1588	44.4500	29.2912	1.9322
	2.37	63.7061	25.3724	60.1980	34.8256	1.3725
18	0.75	15.9132	6.4958	19.0500	12.5542	1.9326
	1.60	36.7529	15.0028	40.6400	25.6372	1.7088
	2.20	61.7083	25.1898	55.8800	30.6902	1.2183
19	0.95	20.8045	8.4925	24.1300	15.6375	1.8413
	1.25	37.6139	15.3543	31.7500	16.3957	1.0678
	2.37	62.4658	25.4990	60.1980	34.6990	1.3607

TABLE V (Continued)

RELATIVE PORE VOLUME OF COATINGS
ON BLACK GLASS SUBSTRATE

No.	Thickness in.	Coat Wt. g/m ²	Theoretical Volume	Actual Volume	Pore Volume	Relative Pore Volume
20	0.95	22.1308	9.0339	24.1300	15.0961	1.6710
	1.00	30.1394	12.3030	25.4000	13.0970	1.0645
	2.10	68.1839	27.8332	53.3400	25.5068	0.9164
21	0.95	21.8033	8.9002	24.1300	15.2298	1.7111
	1.20	39.5428	16.1416	30.4800	14.3384	0.8882
	2.10	63.7921	26.0404	53.3400	27.2996	1.0483
22	0.95	15.3966	6.5595	24.1300	17.5705	2.6786
	1.70	37.3036	17.6075	43.1800	25.5725	1.4523
	2.10	61.2260	26.0847	53.3400	27.2553	1.0448
23	1.20	22.3717	9.5311	30.4800	20.9489	2.1979
	1.10	38.5439	16.4212	27.9400	11.5188	0.7014
	2.10	55.7321	23.7441	53.3400	29.5959	1.2464
24	0.95	17.0499	7.2639	24.1300	16.8661	2.3219
	1.10	38.1647	16.2597	27.9400	11.6803	0.7183
	2.10	63.0859	26.8771	53.3400	26.4629	0.9845
25	1.00	22.3888	9.5384	25.4000	15.8616	1.6629
	1.20	38.0787	16.2230	30.4800	14.2570	0.8788
	1.80	55.3011	23.5605	45.7200	22.1595	0.9405

TABLE VI
UNCALENDERED 75° GLOSS OF
COATINGS ON PAPER SUBSTRATE

No.	Coat Wt. g/m ²	Gloss	No.	Coat Wt. g/m ²	Gloss
1					
2	20.5494	26.76	8	14.1133	12.10
	30.7112	20.63		25.0282	10.26
	45.5024	17.30		31.6900	9.98
	82.0100	25.40		61.6863	7.76
	11.4412	45.83		22.0174	10.64
3	20.9257	27.56	9	18.5545	12.72
	32.1040	22.53		24.4638	12.82
	45.2390	19.46		32.7436	13.02
	83.9672	18.56		61.1595	13.22
	12.7587	26.93		10.9114	11.74
4	19.2319	24.26	10	13.1350	15.82
	31.5390	22.03		20.6999	12.14
	43.7338	19.23		30.3725	9.46
	80.1661	17.13		57.6214	7.24
	14.2262	24.23		7.6778	15.82
5	20.4365	25.36	11	12.7587	15.70
	31.7277	22.73		19.4957	13.36
	43.8091	20.60		31.2004	10.82
	81.1445	18.76		50.9596	8.78
	15.6942	25.06		7.8283	14.78
6	11.9303	8.78	12	13.1350	18.48
	23.9741	6.84		22.3932	17.90
	32.8565	6.00		32.2921	14.92
	62.4389	4.22		48.9276	13.26
	5.8334	7.78		4.4431	14.44
7	16.5973	10.02	13	12.8339	20.30
	20.8128	8.86		22.5442	20.52
	31.0122	7.20		31.9534	18.90
	65.9770	5.22		59.8796	15.58
	8.5809	9.26		4.9680	16.76

TABLE VI (Continued)

UNCALENDERED 75° GLOSS OF
COATINGS ON PAPER SUBSTRATE

No.	Coat Wt. g/m ²	Gloss	No.	Coat Wt. g/m ²	Gloss
14	13.9252	13.32	20	14.5649	19.94
	20.5870	11.18		22.9581	23.18
	30.3725	10.06		33.8725	24.34
	55.8147	6.68		59.7667	27.08
	8.5056	12.12		7.3767	13.72
15	14.5272	16.48	21	15.2803	17.56
	20.6999	16.18		22.5818	18.32
	31.7653	15.28		31.9911	18.64
	60.9714	12.34		61.2348	18.30
	5.9463	15.90		5.9087	14.40
16	12.8339	15.92			
	19.6463	15.84			
	30.5230	14.14			
	57.9977	11.26			
	5.8334	14.08			
17.	13.9628	17.22			
	23.1086	18.10			
	31.0498	17.48			
	61.0842	16.00			
	5.7958	15.00			
18	11.2906	11.30			
	23.2592	10.78			
	32.2168	9.40			
	62.5874	7.60			
	7.3391	9.68			
19	12.7210	13.12			
	20.9257	12.46			
	31.8405	11.20			
	59.2023	9.14			
	7.6401	12.18			