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PIGMENTS DEPARTMENT

EXPERIMENTAL STATION

INTERIM REPORT

FORMULATION OF FLAT PAINTS

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INTERIM REPORT

FORMULATION OF FLAT PAINTS

by

O. B. Willcox

Project

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INTERIM REPORT

FORMULATION OF FLAT PAINTS

A. INTRODUCTION

1. Objective

(a) The major purpose of the work reported here was to provide a body of quantitative information on the formulation of flat paints and rapid methods for screening evaluation of new pigment candidates prior to more detailed study by experienced formulators.

2. Importance

(a) Flat paints are possibly the largest single end use of white pigments. They are complex systems. No single general detailed explanation of their theory and performance is found in the literature although there is an abundance of narrow studies of specific aspects and compositions. These were mostly written prior to common use of Kubelka Munk scattering coefficients. A typical literature reference is "Fundamentals of Formulating Flat Finishes" (1) which contains a number of formulations but not a single film measurement or other literature reference. A single coherent study was required to reveal inherent advantages of new pigment types with a minimum of formulation study for each candidate.

3. Background

(a) Report WP-ESI-63-12 by the writer was an initial brief, uneducated step towards the objective. Our own understanding and methods have since been improved and tested in use. Reference will be made in the body of the report to pertinent literature.

B. SUMMARY

1. Work Done

(a) A coherent body of information has been assembled using a single alkyd flat vehicle, R-900 TiO_2, and calcium carbonate extenders. The major formulation variables covered were TiO_2 concentration, extender particle size and total pigment concentration.

The effects of these on the following film properties were determined:

- TiO_2 hiding efficiency
- Total film hiding
- Film porosity
- Gloss.

(b) New laboratory methods of preparing paints on a miniature scale (13 cc or less) and accurately determining the important properties were devised. Suitable equipment was acquired and personnel trained in these methods.

2. Important Results

(a) An improved quantitative understanding of conventional flat paint systems has been outlined.

(b) The information has been useful in the evaluation of new pigment candidates.

C. CONCLUSIONS AND RECOMMENDATIONS

(a) Large improvements in flat paints are possible.

(b) Extension of this study to include the finer points of formulation and performance would be useful.

(c) The information should generally apply to latex type and other extended systems but the study should be repeated for latex paints.

D. PLANS FOR FUTURE WORK

(a) Repeat on a limited basis for a typical latex vehicle.

(b) Carry out a similar study on a radically different type of extended pigment now under study.

E. DISCUSSION

1. General Applicability of Study

Most flat paints are used on interior surfaces. Interior semigloss paints and some exterior paints employ extenders and the general considerations developed in this report might be pertinent. They might also apply to any pigmented system containing extenders or an extender-like component such as paper.

2. Flat Paints - Function and Properties

A flat paint is designed to provide an adherent film of uniform color and low gloss over a base of different and uneven color, gloss and porosity. In addition, it is expected to be stable in storage, easily applied, dry rapidly, allow working with the applicator for some time after the film has been applied without change of color or gloss in the dried film, show little color or hiding change during the drying process, fill minor cracks and surface imperfections, have low odor, be resistant to various stains and water spotting, easily cleaned, scuff resistant, maintain its properties on aging, provide a base for repainting and be low in cost.

3. Glossary

(a) PVC, pigment volume concentration, is the volume of pigment (TiO_2, extender or any inert insoluble component) divided by the volume of the pigment plus the volume of the binder or film forming components.

(b) CPVC, critical pigment volume concentration. As the PVC of a film is increased, its properties show a gradual change until the solid inert particles attain a certain packing density and the void spaces are exactly filled with the available binder. Increased pigment beyond this point results in film voids and abrupt changes in film properties. This is the CPVC. The CPVC is determined by the size, shape and size distribution of the solids, their surface area and the degree of dispersion and wetting of the solids by the binder. A complete discussion can be found in Paint Flow and Pigment Dispersion (2).

(c) "Free" TiO_2 PVC. This is the volume of TiO_2 divided by the volume of TiO_2 plus the volume of binder in the dry film.

(d) % voids. The volume of connected air voids in the dry film divided by the total film volume (air voids plus film solids volume).

(e) S_W. This is a measure of the scattering value of a unit weight (or volume) of TiO_2. It is defined here as the

Kubelka-Munk scattering value, Sx as determined from Ross curves in report PTW-8-2-64, of the film when spread at such thickness that an area of 25 cm^2 contains 0.03 gs TiO_2. This is equivalent to a spreading rate of 2 lbs TiO_2/814 sq. ft. or 12 gs/m^2 or a TiO_2 thickness of 0.113 mils. Unless otherwise noted this value is for films oiled with Nyjol.

(f) $S_{1\ mil}$. This is the scattering value for a film having a one mil thickness of dry film solids. The actual film may be thicker if it contains air voids.

(g) Crowding refers to the decrease in TiO_2 spacing when a coarse extender replaces binder in a constant volume of paint film.

(h) Window effect. This is a coined term to suggest the fact that light passes directly (without scattering) through large transparent areas of a film which may be extender particles, unpigmented vehicle, or air voids, with a consequent apparent loss of TiO_2 efficiency.

(i) Scattering is the "reflection" of light by refraction and diffraction.

(j) Hiding is the obscuring of a background by scattering and absorption of light.

F. OVERALL EXPERIMENTAL PLAN

1. Experimental Blocks

a. TiO_2 without extender in both alkyd flat and alkyd gloss vehicles.

(b) Paints at 65 PVC with a single extender (Camel-White) and "free" TiO_2 varied from 10 to 40 PVC.

(c) Paints with free TiO_2 PVC of 30, Camel-White and total PVC varied from 45 to 75.

(d) Repeat of C series with each of three extenders of the same composition but increasing size.

(e) Repeat of C but 25 wt. % of the Camel-White replaced by Celite 281.

(f) Paints with extremely large particle size extender (glass beads) to develop window theory.

(g) Stain, scrub, and mar resistance of selected paints.

(h) Testing predictive ability and utility against a commercial flat.

G. RESULTS

1. TiO_2 Without Extenders. Table I and Chart #1

This familiar chart shows the decrease in TiO_2 efficiency as the PVC increases and a maximum hiding for a constant film thickness at about 30 PVC. The absolute values depend upon how well the vehicle wets and disperses the TiO_2 and the size, shape and crystal structure of the TiO_2. It is also shown that a gloss vehicle reduces flocculation and results in an S_W curve parallel to the flat vehicle but about 25% higher.

All films in this report, unless noted otherwise, were dried by placing on horizontal aluminum shelves with air circulating at 35-40°C. When thick wet films of a flat vehicle with R-900 dry slowly at room temperature S_W is lower than those with the more rapid dry as shown by Table 1C. The films at .004" show nearly the same value as the rapid dry but at .006" the values are lower than the rapid dry except at the highest concentrations where values close to the average for rapid dry are obtained. All this is indicative of a time dependent flocculation most noticeable with low concentration, thick wet films and slow drying.

It is noted that the S_W curve is nearly straight between 10 and 40 PVC. Considering the TiO_2 to be perfectly spaced in a simple cubic array and expressing the interparticle distance as a fraction of the TiO_2 diameter, we find:

PVC	Fraction
1	3.45
5	1.19
10	0.74
20	0.38
40	0.10
52.4	0.00

A plot of the fraction vs. S_W is nearly a straight line with only a slight decrease in S_W at 10 to 15 PVC. Steig (3) considered rhombohedral packing the closest packing of spheres. In this case, when the spheres touch the fraction is 0.0 and the PVC 74. The fraction is 1.0 at 9.25 PVC. It is assumed that, since the diameter of TiO_2 particles are about one half the wavelength of green light, scattering will reach a maximum at a fraction of 1 or from 5 to 10 PVC. Accurate measurements are difficult below 10 PVC.

2. Constant PVC Extended Paints. Variable Free TiO_2 PVC

Table IIA shows that the S_W in a 60 PVC paint extended with fine particle size ground natural calcium carbonate corresponds to the S_W of TiO_2 alone in the vehicle but averages slightly higher. The slight difference may be due to several factors. As indicated by the S_X O/D the films contain air spaces which could allow greater separation of the TiO_2 in effect a lower PVC. Part of the air might be in closed pores resulting in TiO_2-air interface and increased hiding. The fine extender may hinder flocculation of the TiO_2. The extender contributes a very small amount of scattering in the oiled film. In any case the difference is small and possibly within experimental error.

Table IIB and Chart 2 show results at 65 PVC with two vehicles. Again the S_W values parallel and are slightly higher than TiO_2 without extender but the gloss vehicle which gave a marked increase in S_W for TiO_2 alone gives nearly identical values in these flats except for a definite decrease in Sx O/D at the highest TiO_2 with the flat vehicle. These films are all above the CPVC where part of the TiO_2 is not wetted even by the gloss vehicle.

Chart 3 and Table IIB show the expected higher gloss and with the gloss vehicle. The PVC curve on this chart shows the packing relationship of the extender and TiO_2 assuming that both pack to 50% voids. A sharp break in this curve is observed at 30 PVC and a break upwards in the gloss curves is seen at the same point. At

40 PVC free TiO_2, the volume of TiO_2 plus the voids between the TiO_2 particles exceeds the void volume between the extender particles and the spacing of the extender would increase and result in higher gloss. A better than 50% packing for the extender or a poorer packing for the TiO_2 would account for the break at 30 PVC free TiO_2.

3. Constant (30 PVC) Free TiO_2 PVC. Total PVC Varied From 45-75 With Each of Five Extender Particle Sizes

Table III gives weight and volume information on films. Table IV characterizes the extenders. Table V gives measurements on films. Photos 1, 2, and 3 show the extenders at 1100X.

(a) S_W Oiled (Chart 4)

From Chart 1, the S_W at 30 PVC free TiO_2 is 2.14. With Camel-White a value of about 2.22 is observed on Chart 2 up to 65 PVC. Reasons for this slightly higher value are given in G-2 above. These data are for single determinations and the accuracy seems to be about $\pm$ 0.05 S_W units. The S_W oiled (except for D) remains fairly constant up to about 65 PVC which is near the CPVC for these calcium carbonates.

The decrease in S_W with increase in extender size is thought to be due to the window effect (see glossary). Part of the minor variations observed may be caused by factors discussed in G-2. A quantitative examination of the window effect is treated separately in this report. Table VI gives the decrease in scattering due to window effect as a % of the value obtained with the finest extender.

Above 65 PVC, S_W increases most rapidly with the finest extender and less rapidly for coarser extenders while the largest extender shows a continuous decrease from 45 to 75 PVC. This sharp rise at high PVC with fine extenders is explained by the fact that the films now contain air voids and the TiO_2 is in effect dispersed in a mixture of vehicle and oiling agent (Nujol), the free TiO_2 PVC in effect being lowered and the S_W therefore increasing. Consider se: A at 75 PVC. This film contains 14% air voids reducing the effective free TiO_2 PVC from 30 to 20.3 which from Chart 1 would have a 2.8 S_W compared to the actual 2.73. This effect decreases with increasing particle size because the air void size also increases and rather than dispersing the TiO_2 the air voids start to act as windows in the same manner as the large transparent extender particles.

(b) <u>S_W Dry (Chart 5)</u>

At the CPVC a sharp increase in S_W results from the formation of TiO_2-air interface. The break points on these curves are: E at 60 PVC; A, B, & C at 65 PVC; D at 70 PVC. Below these points small variation from S_W oiled are due to a slight amount of film porosity before the definite break and also to experimental errors. Above the CPVC both dry hiding and % voids (Chart 7) increase rapidly. It is also noted that the rate of increase of dry hiding is greater the smaller the extender particle size. Steig (4) observed this rate increase and also found that the greater percentage of prime pigment present, the greater the rate of hiding power increase. He found a straight line relationship between dry hiding and the "porosity index" which is defined as the ratio of air voids to the total of vehicle plus air voids. In this report, % voids means % of air voids in the total volume of dry film. Steig's index is calculated from the PVC and the CPVC, but the latter is difficult to determine accurately on the actual film. One method is to measure the cake volume of the filtered paint. Oil absorption tests are only a rough guide. Sharp changes in the hiding power and gloss curves are also a guide. In this report, direct measurement of open pore air voids was made.

The object of the game is to obtain dry hiding without increasing porosity or adversely affecting gloss and other properties. The following table shows how the various extenders perform.

Extender (Table III)	A	B	C	D	E
Paint PVC	75	75	75	75	75
CPVC (by dry S_W inflec.)	65?	65	65	70	60
ΔPVC	10	10	10	5	15
S_W Dry	4.43	3.16	3.04	2.21	4.27
S_W Oil	2.73	2.26	1.99	1.58	2.65
ΔS_W	1.70	.90	1.05	.63	1.62
% Voids	13.7	11.4	15.4	14.4	27.8
ΔS_W x 100/% Voids	12.4	7.9	6.8	4.4	5.9
S_W dry x 100/% Voids	32.4	27.7	19.7	15.3	15.3
Gloss-85°	20.9	7.0	5.8	4.4	5.0

It can be seen that the best hiding/void ratio is obtained with the finest extender, but this is at the expense of 85° gloss, increased stain retention and poorer scrub resistance. Addition of celite decreases gloss but increases voids drastically. Additional discussion of the balancing of properties will be found in later sections.

(c) $S_{1\ mil}$ Oiled (Chart 6)

This demonstrates the obvious; at a constant free TiO_2 PVC and constant dry film thickness hiding power drops continuously with increasing PVC since the extender volume is increasing and the volume of TiO_2 is decreasing.

(d) $S_{1\ mil}$ Dry (Chart 7)

This shows that at constant free TiO_2 PVC the increase in dry hiding obtained by raising the PVC is counteracted by the decreased TiO_2 so that an advantage results only with the finest extender. The results are the same when celite is added to decrease the gloss and, as was shown in G-3-b, celite increases film voids drastically.

The general coincidence of curves B & C in spite of the appreciable size difference appears to be related to a better packing for B as shown by decreased % voids although the given particle size distribution yields no clue to explain a better packing.

(e) S_x O/D (Chart 8)

High values are subject to an error of ±5%. This ratio is commonly used as a rough measure of film integrity. Few commercial paints have a value below 70%.

(f) % Voids-Actual (Chart 9)

It can be seen that the % voids are similar for the smalles and largest extender. B extender (Camel Tex) shows the best packing while the celite is very poor due to its irregular shape. Poor packing means that the CPVC is decreased.

(g) <u>% Voids-Calculated (Chart 10)</u>

A family of curves is given showing the % voids-PVC relation if it is assumed that the total pigment packs to percentages from 40 to 65% of the theoretical maximum. It can be seen that the actual curves closely parallel the calculated curves. Maximum packing values are accurately determined by this chart.

(h) <u>% Voids for Various Extender Packings (Chart 11)</u>

In this chart the voids have been calculated for 30 PVC TiO_2 paints assuming that the TiO_2 plus vehicle phase behaves as pure vehicle. This is perhaps more informative than chart 10. Under these circumstances the A extender shows near zero voids at 65 PVC paint (50 PVC extender) and the extender packing appears to be 50%. At 75 PVC paint the actual voids correspond to 55% extender packing. This might be expected because capillary forces could be greater in the more porous high PVC films. However, chart 10 shows that the combined extender and TiO_2 maintain a constant packing. This can be rationalized by noting that the ratios of extender to TiO_2 volumes are 1.85 at 55 PVC and 6.0 at 75 PVC. A large volume of TiO_2 at the low PVC packs between the extender voids and compensates for the poorer packing of the extender.

(i) <u>Gloss-60° & 85° (Charts 12 & 13)</u>

These have been plotted on a log chart to show small differences at low gloss values. Incidentally, it is noted that the curves are nearly straight lines on either side of the CPVC.

The most interesting observation is that the gloss actually increases slightly above the CPVC. This is probably due to expansion of the TiO_2-vehicle phase by air which would tend to decrease the depth of the valley between protruding large extender particles.

H. <u>DETAILED EVALUATION</u>

Section G covered the basic properties. Certain significant end use tests are more laborious and less exact. Some of these, but not all (see E-2), have been made on four formulations as shown in Table VII. These were repeat paints.

The results are summarized as follows (see photos 4 & 5):

1. <u>Scrub Resistance</u> is proportional to the S_x O/D as expected because this ratio is a measure of the completeness of pigment coverage by the binder.

2. <u>Resistance to soluble stains</u> is least for the fine extenders presumably because of the finer pore size and greater capillarity. Pore volume does not dominate.

3. <u>Resistance to removal of oily, pigmented stains</u> by wiping is least for large particle size extenders. In all cases these require a detergent fluid and a coarse scrubbing brush or cloth for satisfactory removal.

4. <u>Gloss increase on rubbing</u> is greatest with the fine extender even with celite added to decrease the initial gloss.

If one attempts to reduce the poor integrity of the celite dulled film by reducing the PVC, much of the 1 mil dry hiding advantage is lost and the disadvantage of higher porosity and smaller pores persists down to 50-55 PVC. At this point, the 1 mil hiding advantage is regained but the cost increases sharply due to higher TiO_2 and dry binder content.

For these and other reasons the general practice is to compromise cost and each aspect of performance. The formulation then becomes more complex. An example of such compromise is given in the next section.

I. SAMPLE FORMULATION

The label analysis of a high quality commercial flat "enamel" gave the following composition in terms of volume percent of a dry film.

Total PVC	- 59.3
Binder	- 40.8
$CaCO_3$	- 27.4
$CaSO_4$ *	- 3.46
SiO_2 **	- 8.10
TiO_2	- 20.35
"Free" TiO_2 PVC	- 33.2

* Fine particle size extender ~2μ or less.
** Presumably a diatomaceous earth-like Celite.

The charts were examined and two formulations were chosen to yield average properties that would closely duplicate the commercial product. These are shown in Table VIII. The result is very close. Increasing the TiO_2 content would bring it even closer to the commercial product. The assumption is made that the averaging would be correct within the accuracy of the testing methods.

J. VEHICLES

1. Flat Vehicle - Contains 0.264 cc solids (1.05 Sp.Gr.) per cc of vehicle.

ADM 3025-P-40	- 380 gs.
Naptha	- 70 cc
Drier Mix*	- 16.3 cc

* 24% Pb	- 8.1 gms
6% Co	- 3.25 gms
Antiskin Agent	- 5.0 gms
Naptha	- 50.0 gms

2. Gloss Vehicle - Contains 0.413 cc solids (1.05 Sp.Gr.) per cc of vehicle.

Aroplaz 2502	- 550 gms
Naptha	- 126 gms
Drier Mix*	- 7.3 gms
Soya Lecithin	- 3.0 gms

* 24% Pb	- 24.6 gms
6% Co	- 13.2 gms
ASA	- 6.0 gms

3. Red Oil for % voids determination.

100 cc Nujol
4 cc 3-in-1 lubricating oil
0.1 gm oil soluble red A dye

K. METHODS

1. Paint Formulation is calculated on the basis of 100 cc of dry paint film solids. From these the volume of vehicle and grams of pigments required for 13 cc of paint are calculated. Significant volume relationships and the specific gravity and wt.% TiO_2 in the dry film are tabulated.

2. Paint Preparation. The required ingredients are measured into a glass vial about 2.5" high x 1 1/8" diam. with an internal volume of 35 cc and roughly mixed with a stainless spatula and

additional naptha added to obtain a normal paint consistency. Ten cc of 4 mm Pyrex beads are added and the vials closed with a flat polyethylene cap. Two vials are clamped in a Spex Industries Model 8000 mill and shaken for 10 min. Enamels are mixed for 30 minutes.

3. Film Application. Films are applied to a Morest hiding power chart form 09 using a 4 or 6 mil clearance x 3 inch wide Bird applicator and a Gardner mechanical drive. A Bird applicator with 6 mil clearance and 1 1/2 inches width is used by hand to make two drawdowns on a sheet of 2 mil Mylar® 5 3/4" x 10". In general, the test accuracy is such that only a 4 mil film on paper and one of the 6 mil films on Mylar is required. These are dried on a horizontal position in the laboratory without controlled temperature or humidity. Drying can be accelerated as discussed in the report and in certain cases drastically affects the results.

4. Film Measurements. (a) Scattering Values. Reflectance on the hiding power chart is measured with a Gardner automatic reflectometer over the two black and two white areas. A brass template 1 3/8" x 2 3/4" and a knife is used to cut out a piece of the lower white section (between the two blacks). This has an area of 25 cm^2. A coating of Nujol is brushed on the remaining film and allowed to penetrate for 30 minutes. Reflectance is measured on the top white and two black sections. Reflectances are averaged giving R_o & R_w. S_x values are read from the curves in Ross' report PTW-8-2-64. A reading of the reflectance of the white portion of

the card is made once for each series. The white cut out is weighed, the paint and lacquer is stripped with acetone, and the paper dried at room temperature for 10 minutes and weighed again. The card lacquer weight is also determined by removal with acetone and then the paint weight calculated. When a new vehicle batch is used the paint removed is ashed and % TiO_2 is determined and checked against the calculated value.

$$S_W = \frac{S_x \times 3}{\text{gs paint} \times \text{wt. \% } TiO_2 \text{ in dry film}}$$

$$S_{1\ mil} = \frac{S_x \times \text{Sp. Gr. of paint film} \times 0.0635}{\text{gm paint}}$$

5. <u>% Voids and Gloss - (a) % Voids</u>. A rectangular piece is cut from the drawdown on Mylar® using the same template. This is weighed and then painted with red oil (J-3) and allowed to stand for 1/2 hr. The excess oil is removed with a flat rubber squeegee. The surface is wiped to a uniform sheen using the forefinger and repeatedly wiping the finger on filter paper. The underside is wiped clean with filter paper and the specimen weighed. The film and oil are removed with acetone and the Mylar weighed. The weight of paint and absorbed oil are calculated. The volume of voids = gms oil absorbed ÷ 0.882 = cc oil.

$$\text{\% Voids} = \frac{\text{cc oil}}{\text{gms paint/Sp.Gr. paint} + \text{cc oil}} \times 100$$

This test is most accurate when a blank is run on a nonporous film having about the same degree of surface roughness since the wiping leaves a small amount of surface oil behind the irregularities. It has been found to be more reliable than measurements with a dial micrometer because in the thickness measurement the film is compressed, weighing is more sensitive than the dial which must be estimated below 0.1 mil, the area measured by the dial is a small proportion of the whole. Roughness probably results in a greater error with thickness measurement than the weighing.

(b) Gloss. 60° and 85° gloss were measured on the Mylar® before the void determination.

L. DISCUSSION OF WINDOW EFFECT

W. D. Ross has considered the theoretical aspects of the window effect and proposed the equation F = 3/2 + 2 PSD where F is the ratio by which the apparent scattering of the paint surrounding the extender is lowered, P is the volume fraction of extender in the film, D is the extender diameter in microns, and S is the scattering in reciprocal microns of the paint surrounding the extender. According to chart 1, S_w at 30 PVC TiO_2 is 2.14 making S (Ross) = $\frac{2.14}{12}$ = 0.178. $S_{1\ mil}$ for the TiO_2 alone is 5.72, then S_w = 2.14F and $S_{1\ mil}$ = 5.72 x F x (1-P).

PVC	F		Calculated				Actual			
	2μ	10μ	2μ S_w	10μ S_w	2μ $S_{1\ mil}$	10μ $S_{1\ mil}$	2μ S_w	10μ S_w	2μ S_{1mil}	10μ S_{1mil}
45	.952	.798	2.04	1.71	4.34	3.64	2.21	1.99	4.62	4.16
50	.937	.745	2.01	1.59	3.82	3.03	2.15	1.88	4.10	3.57
55	.922	.702	1.97	1.50	3.39	2.58	2.26	1.85	3.87	3.17
60	.907	.660	1.94	1.41	2.96	2.15	2.24	1.71	3.39	2.59
65	.894	.627	1.91	1.34	2.56	1.79	2.24	1.70	2.98	2.26
70	.880	.595	1.89	1.27	2.16	1.46	2.46	1.65	2.82	1.88
75	.867	.567	1.86	1.21	1.77	1.16	2.73	1.58	2.60	1.51

These calculated values for 2μ extender show only a slight continuous decrease in S_W. The actual increase has been explained in this report as due to expansion of the film with increased PVC and consequent effective decrease of the TiO_2 PVC. The S_W calculated for the 10μ extender is uniformly about 0.3 unit too low and the calculated $S_{1\ mil}$ value for 10μ is about 0.45 unit low. If 0.6 unit is added to the calculated $S_{1\ mil}$ and the S_W calculated from this, the values increase above 55 PVC for the 2μ extender and show good agreement with the actual results.

At 65 PVC and 30 PVC free TiO_2 the dependence of S_W on particle size of the extender is accurately given by the empirical equations:

$$F = \frac{1}{D\ 1/3 + 2} \qquad \text{and} \qquad S_W = F \times S_{W(2)}$$

where D is the extender diameter in microns and $S_{W(2)}$ is the determined value for a 2 micron extender particle.

D	F	S_W Calc.	Actual	Act.-Calc.
2	1.0	2.24	2.24	0.0
4	0.905	2.02	2.00	- .02
7.5	0.820	1.84	1.93	+ .07
10	0.785	1.76	1.70	- .06
30	0.640	1.44	1.56	- .12
40	0.603	1.35	1.32	+ .03

The 30 and 40 micron paints were made with Flex-O-Lite glass beads. Other properties of these paints were:

	30μ	40μ
S_W - oil	1.56	1.32
S_W - dry	1.62	1.52
$S_{1\ mil}$ - oil	2.13	1.80
$S_{1\ mil}$ - dry	2.22	2.08
S_x O/D	96.5	86.0
Gloss - 60°	3.4	3.4
Gloss - 85°	2.4	2.3
% Voids	12	14.7

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(2) T. C. Patton, Paint Flow & Pigment Dispersion, Wiley (1964).

(3) F. B. Steig, Jr., Official Digest Federation of Societies for Paint Technology, June 1959.

(4) F. B. Steig, Jr., Official Digest Federation of Societies for Paint Technology, July 1961.

TABLE I

TiO_2 ONLY

A - Flat Vehicle

PVC-R-900	10	15	20	25	30	35	40
Wt. % TiO_2 in Film	30.7	41.4	50.0	57.1	63.2	68.2	72.7
Sp.Gr. Film	1.37	1.52	1.68	1.84	2.00	2.15	2.31
SW - .004"	3.43	3.18	2.74	2.36	2.11	1.87	1.58
SW - .006"	3.75	3.22	2.81	2.69	2.19	1.85	1.47
SW - Av.	3.59	3.20	2.78	2.53	2.15	1.86	1.53
S-1 mil-.004"	3.03	4.23	4.85	5.24	5.61	5.79	5.59
S-1 mil-.006"	3.31	4.28	4.98	5.65	5.84	5.73	5.23

B - Gloss Vehicle

SW - .004"		4.06	3.59	3.21	2.81		
SW - .006"		3.65	3.44	2.98	2.82		
SW - Av.		3.86	3.52	3.10	2.82		

C - Flat Vehicle - Room Temperature Dry

SW - .004"		2.77	2.71	2.57	2.19		
SW - .006"		2.00	2.07	1.98	1.95		

TABLE II

CONSTANT PVC EXTENDED PAINTS

VARIABLE FREE TiO_2 PVC

Free TiO_2 PVC	10	15	20	25	30	35	40
TiO_2 PVC	3.9	6.17	8.75	11.65	15.0	18.85	23.3
Extender PVC	61.1	58.83	56.25	53.35	50.0	46.15	41.7
Wt.% TiO_2 in Pigment	8.85	14.0	19.5	25.4	31.8	38.9	46.5
Wt.% TiO_2 in Film	7.35	11.7	16.3	21.3	26.8	32.9	39.6
Sp. Gr. of Film	2.18	2.22	2.26	2.30	2.35	2.41	2.47

A - 60 PVC, R-900, Camel White Rapid Dry

Flat Vehicle	10	15	20	25	30	35	40
Oiled SW - .004"		3.43	2.86	2.64	2.26		
Oiled SW - .006"		3.55	2.78	2.55	2.32		
Oiled SW - Av.		3.49	2.82	2.61	2.29		
SW Enamel-Table IA	3.59	3.20	2.78	2.53	2.15	1.86	1.53
Sx O/D		91.0	92.3	94.2	98.5		

B - 65 PVC, R-900, Camel White Room Temperature Dry

Flat Vehicle	10	15	20	25	30	35	40
Oiled SW - .004	4.17	3.32	3.08	2.58	2.40	1.94	1.76
S_1 mil	1.41	1.82	2.39	2.70	3.20	3.24	3.62
Sx O/D	85.8	88.8	88.5	89.8	88.8	88.8	83.0
% Voids	5.3	4.1	5.0	4.0	6.1	2.7	4.4
Gloss - 60°	4.4	4.5	5.0	5.4	5.7	6.8	8.1
Gloss - 85°	12.9	12.9	13.3	15.1	16.4	20.3	25.9
Gloss Vehicle							
Oiled SW - .004"	3.84	3.40	2.96	2.56	2.27	2.06	1.84
S_1 mil	1.30	1.86	2.30	2.65	3.70	3.45	3.79
Sx O/D	87.0	92.7	90.0	90.3	88.0	88.8	90.0
% Voids	3.5	2.7	3.0	3.2	2.0	1.7	2.7
Gloss - 60°	4.9	5.3	5.4	6.5	6.7	8.4	9.4
Gloss - 85°	22.2	18.9	20.7	22.0	23.5	25.1	32.6
Enamel-Table IA		3.86	3.52	3.10	2.82		

TABLE III

VOLUME RELATIONS

FLAT PAINTS - PVC EXTENDER SIZE VARIATIONS

Set #	Paint #	PVC Paint	PVC Free TiO_2	PVC TiO_2	PVC $CaCO_3$	PVC Celite	Wt. % TiO_2 in Film	Wt. % TiO_2 in Pig.	Sp.Gr. Film
A*	1	45	30	23.6	21.4	--	46.1	63.1	2.15
	2	50	30	21.4	28.6	--	41.0	53.7	2.20
	3	55	30	19.3	35.7	--	36.1	45.6	2.25
	4	60	30	17.1	42.9	--	31.2	38.2	2.30
	5	65	30	15.0	50.0	--	26.8	31.8	2.35
	6	70	30	12.9	57.1	--	22.6	26.0	2.40
	7	75	30	10.7	64.3	--	18.4	21.6	2.45
E	33	45	30	23.6	15.4	6.0	46.0	63.0	2.12
	34	50	30	21.4	20.5	8.1	41.5	54.7	2.17
	35	55	30	19.3	25.6	10.1	36.6	46.5	2.21
	36	60	30	17.1	30.8	12.1	31.8	39.1	2.26
	37	65	30	15.6	35.9	14.1	27.4	32.6	2.30
	38	70	30	12.9	41.0	16.1	23.1	26.8	2.34
	39	75	30	10.7	46.2	18.1	18.9	21.2	2.38

*Sets B, C, D same as A

A - Camel White
B - Camel Tex
C - Camel Carb
D - #10 White
E - 75% Camel White, 25% Celite 281

TABLE IV

EXTENDER PROPERTIES

Extender	Camel White	Camel Tex	Camel Carb	#10 White	Celite #281
Info From Supplier					
ASTM SSD (μ diam.)	2.0	4.0	7.5	5+	
Coarseness	10	30	44	44	
Distribution					
% Finer than μ	100-15 98-10 72-5 40-2	99-30 92-20 86-15 76-10 54-5 28-2	99.5-44 97-40 89-30 78-20 70-15 58-10 40-5 19-2	99-40 86-30 68-20 40-10 26-6 20-4 14-2	2 to 12 μ
Oil Absorption	15	14	13	7-9	
Our Testing					
Specific Surface m^2/g	3.1	2.3	2.1	<1	2.0
Median Ø by wt. from microscope				10.0	

TABLE V

ALKYD FLAT SERIES

Set	#	PVC Paint	Gloss 60°	Gloss 85°	SW O	SW D	S_1 mil O	S_1 mil D	Sx O/D	% Voids	cc Naptha[1]
A	1	34	39.6	68.9	2.21	2.21	4.62	4.62	100	2.6	0.4
	2	50	23.5	47.9	2.15	2.18	4.10	4.15	98.8	0.2	0.4
	3	55	13.2	27.3	2.26	2.26	3.87	3.87	100	0.0	0.4
Camel White	4	60	7.1	15.9	2.24	2.41	3.39	3.64	93.1	1.7	0.4
	5	65	6.0	15.3	2.24	2.58	2.98	3.44	86.7	2.5	0.5
	6	70	6.0	17.5	2.46	3.35	2.82	3.85	73.4	9.0	1.3
	7	75	6.0	20.9	2.73	4.43	2.60	4.23	61.5	13.7	2.1
	8*	30	88.6	92.3	1.96	2.02	5.22	5.40	96.7	2.4	0
B	9	45	36.2	56.9	2.01	2.04	4.21	4.33	98.7	0.7	0
	10	50	19.4	29.7	1.97	1.99	3.74	3.79	98.7	0.1	0
	11	55	10.7	13.0	2.01	2.12	3.44	3.63	94.8	0.0	0
Camel Tex	12	60	6.9	7.7	2.11	2.23	3.20	3.38	94.8	1.3	0.4
	13	65	4.7	6.1	2.00	2.18	2.66	2.89	92.2	3.2	0.5
	14	70	4.8	6.2	2.14	2.52	2.45	2.88	85.1	5.0	1.4
	15	75	5.3	7.0	2.26	3.16	2.15	2.97	71.5	11.4	1.6
	16*	30	88.1	93.0	2.02	2.02	5.38	5.38	100	0.3	0
C	17	45	32.0	46.0	1.99	2.04	4.16	4.27	97.5	2.9	0
	18	50	17.0	19.7	1.83	1.88	3.47	3.57	97.2	0.0	0
	19	55	10.0	9.3	2.00	2.09	3.42	3.58	95.6	3.9	0.4
	20	60	6.4	5.4	1.85	2.20	2.80	3.33	84.1	3.3	0.4
Camel Carb	21	65	5.3	5.0	1.93	2.22	2.56	2.95	86.8	6.3	0.6
	22	70	5.2	5.1	1.96	2.50	2.24	2.90	77.2	11.8	1.2
	23	75	5.9	5.8	1.99	3.04	1.89	2.88	65.6	15.4	1.5
	24*	30	90.6	91.6	2.18	2.18	5.82	5.82	100	7.8	0
D	25	45	35.7	48.3	1.99	2.09	4.16	4.37	95.3	0.0	0
	26	50	18.7	17.2	1.88	1.96	3.57	3.67	97.2	1.7	0
	27	55	10.0	7.9	1.85	1.96	3.17	3.36	94.3	3.4	0
#10 White	28	60	6.3	4.9	1.71	1.93	2.59	2.93	88.4	3.7	0.5
	29	65	4.9	4.0	1.70	1.93	2.26	2.56	88.4	6.7	0.4
	30	70	5.0	4.2	1.65	1.96	1.88	2.24	83.8	10.4	1.0
	31	75	5.7	4.4	1.58	2.21	1.51	2.11	71.6	14.4	1.9
	32*	30	--	--	2.05	2.13	5.47	5.69	96.1	7.2	0
E	33	45	19.1	28.8	2.22	2.17	4.56	4.46	102	0	0.5
	34	50	10.3	6.5	2.14	2.24	4.07	4.26	95.5	0.4	0.5
Camel White	35	55	5.6	5.3	2.22	2.36	3.79	4.02	94.2	3.5	0.8
25 wt.%	36	60	3.7	3.7	2.35	2.43	3.54	3.67	96.4	7.0	1.2
Celite 281	37	65	3.8	4.1	2.30	2.84	3.06	3.78	81.0	14.3	1.7
	38	70	4.2	4.5	2.34	3.41	2.67	3.89	68.6	21.4	2.4
	39	75	4.2	5.0	2.65	4.27	2.52	4.06	62.0	27.8	3.5
	40*	30	84	95	2.42	2.42	6.44	6.44	100	3.9	0
*TiO_2 Control	Av.	30	87.8	93.0	2.05	2.06	5.47	5.57	98.2	4.4	0

(1) Added to 13 cc grinds to give about the same consistency for application.

TABLE VI

EFFECT OF EXTENDER ON S VALUE

% OF SW OILED WITH FINEST EXTENDER (CAMEL WHITE)

Extender	Camel White	Camel Tex	Camel Carb	#10 White	Celite + Camel White
Table IV, Set #	A	B	C	D	E
Paint PVC					
45	100	91	90	90	101
50	100	91.5	85	87.5	100
55	100	89	88.5	82	98.5
60	100	94	82.5	76.5	105
65	100	89.5	86	76	103
70	100	87	79.5	67	95
75	100	83	73	58	97

TABLE VII

EVALUATION OF 70 PVC PAINTS

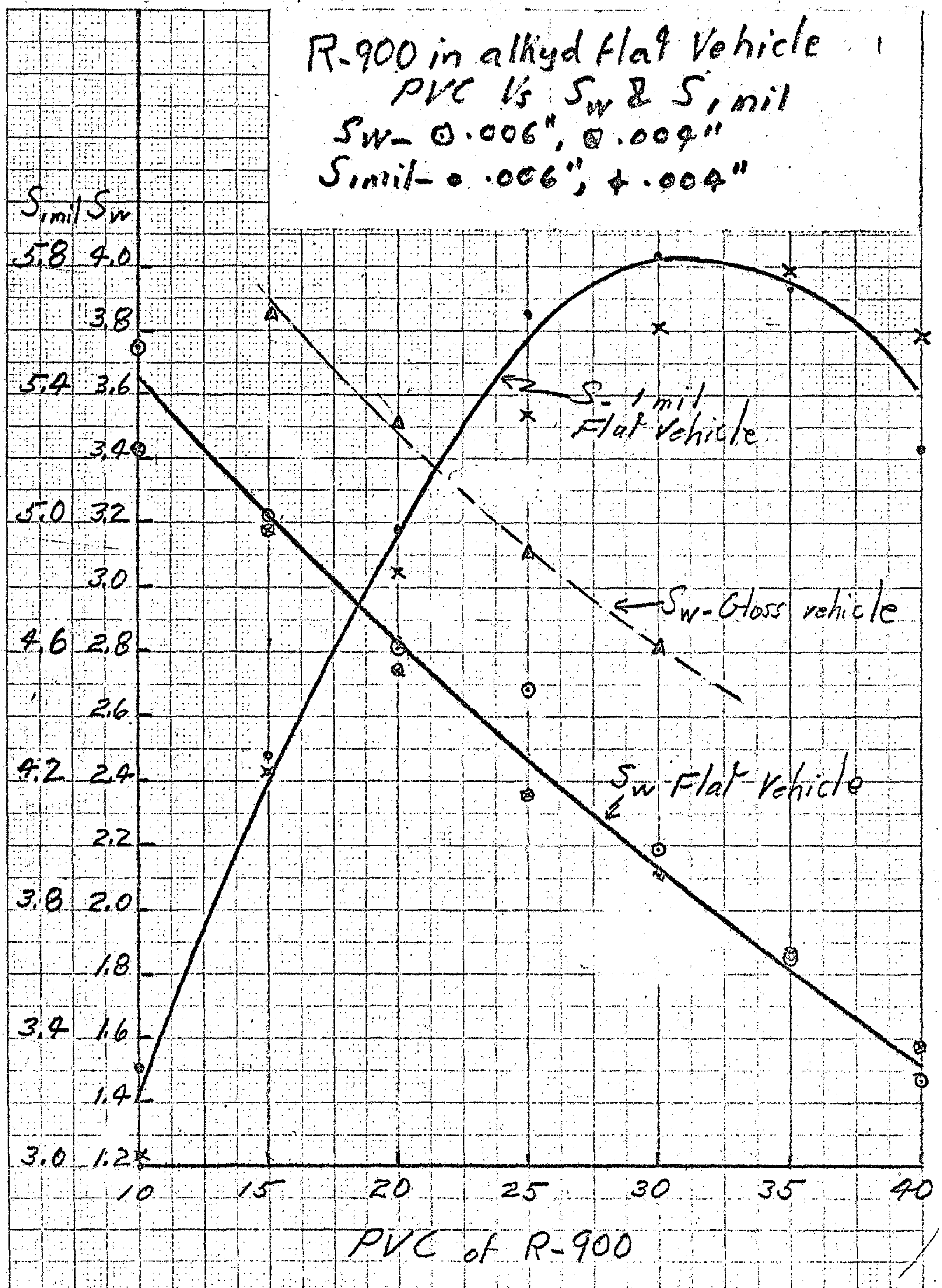
Paint #	6		22		30		38	
Set	A		C		D		E	
Extender	Camel White		Camel Carb		#10 White		C.W. + Celite	
Text	A	B	A	B	A	B	A	B
SW Oil	2.46	2.44	1.96	1.99	1.65	1.57	2.34	2.29
SW Dry	3.35	3.08	2.50	2.35	1.96	1.89	3.41	3.48
S_1 mil Oil	2.82	2.79	2.24	2.28	1.88	11.80	2.67	2.61
S_1 mil Dry	3.85	3.52	2.90	2.69	2.24	2.16	3.89	3.97
Sx O/D	73.4	79.5	77.2	85.0	83.8	83.0	68.6	67.0
% Voids	11.5	7.4	16.2	10.6	19.5	18.0	24.2	24.3
Correction	2.5	2.5	4.4	4.4	9.1	9.1	2.8	2.8
Corrected Voids	9.0	4.9	11.8	6.2	10.4	8.9	21.4	21.5
Gloss 60°	6.0	6.0	5.2	4.9	5.0	5.3	4.2	4.7
Gloss 85°	17.5	14.0	5.1	4.6	4.2	4.0	4.5	5.0
Polished Gloss(1) 60°		12.3		7.0		5.5		6.3
85°		43.3		12.7		8.6		14.7
Gloss gain 60°		6.3		2.1		0.2		1.6
85°		29.3		8.1		4.6		9.7
Gain % Orig. 60°		105		43.0		4.0		34
85°		209		176		115		194
Oiled Reflec.		.886		.863		.846		.870
Black Pigment Paste Reflec.		.670		.548		.434		.513
Reflectance Loss		.216		.315		.412		.357
Red Stain (Merc.)		1 (most)		3		4 (least)		
Scrub-1# brush + Soap-1000 ~	RC* off at 423 ~. BM* remained on all. Polishing as above							
Ajax Slurry-1000 ~								
RC* off at ~		130		430		690		160
BM* off at ~		500		850		980		500
Film failure		Partial		Slight		Slight		Complete740

*Red marking crayon. Black Marks-A-Lot Ink.
(1) Weighted brush

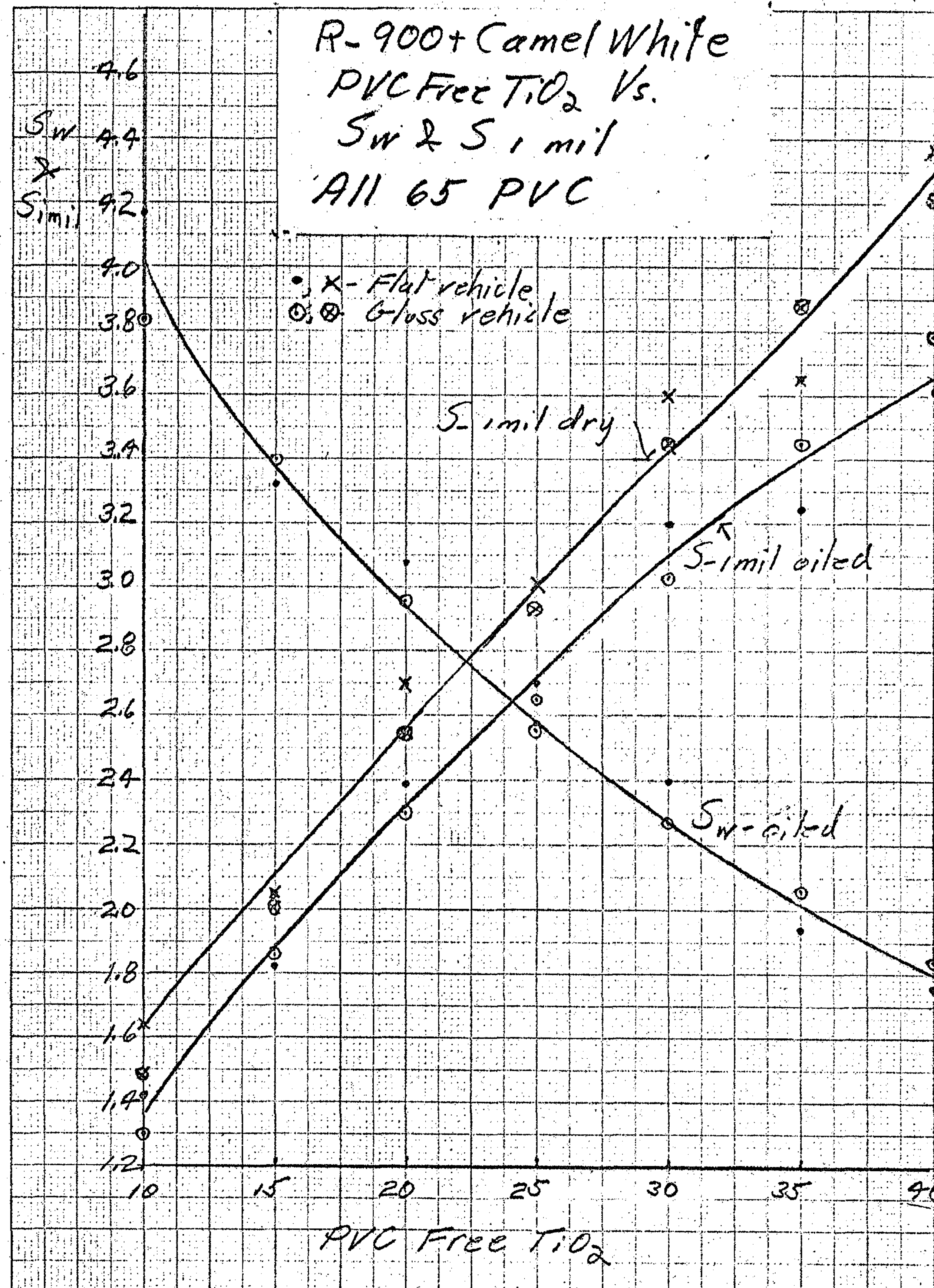
TABLE VIII

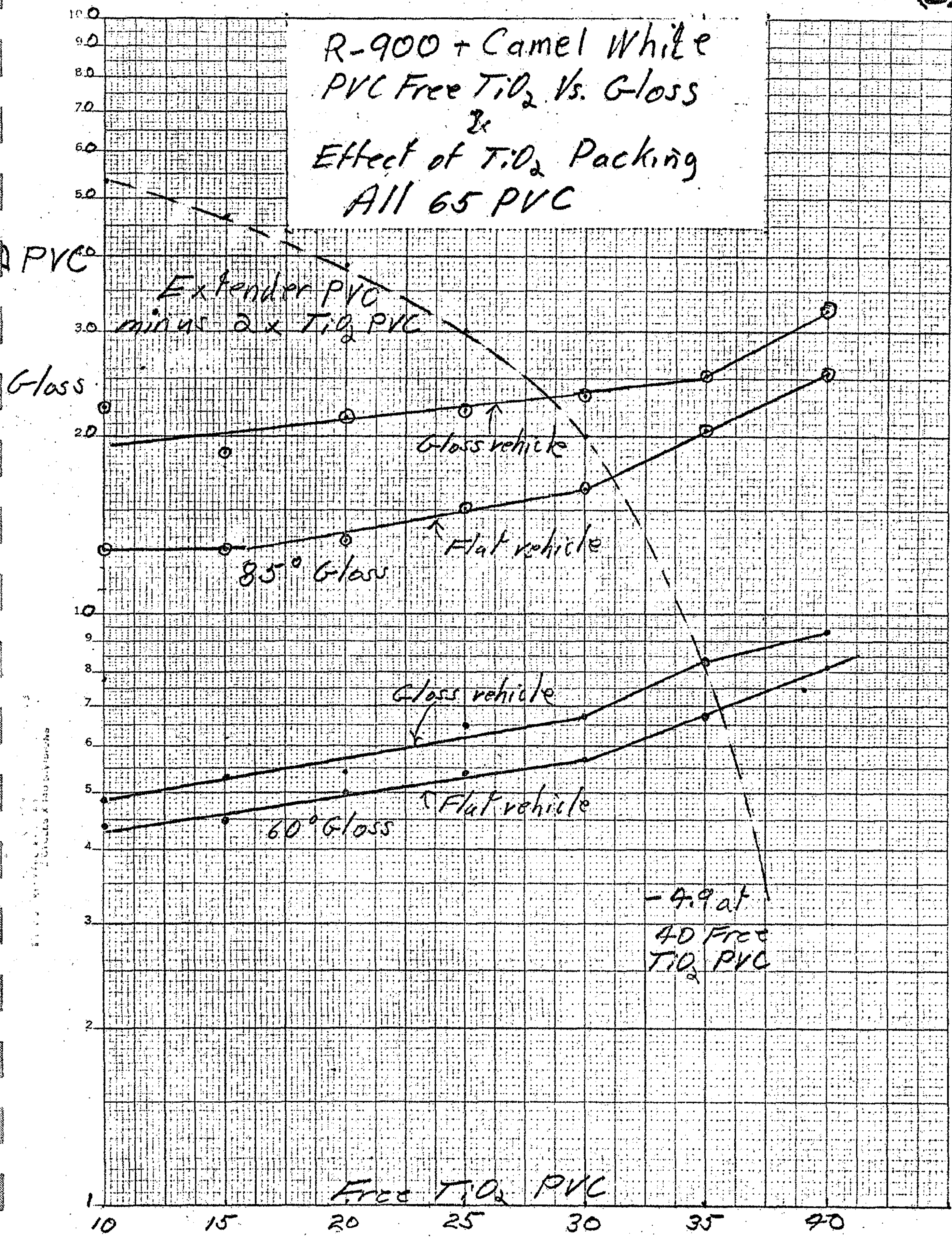
MATCH OF COMMERCIAL FLAT

Extender	Commercial Flat	#36 Camel White + Celite	#14 Camel Tex	Av. #14 #36
PVC	59.3	55	70	62.5
PVC Free TiO_2	33.2	30	30	30
Gloss - 60°	4.1	5.6	4.8	5.2
- 85°	6.2	5.3	6.2	5.7
SW - Oil	2.13	2.22	2.14	2.18
SW - Dry	2.54	2.36	2.52	2.44
S_1 mil Oil	3.18	3.79	2.45	3.12
S_1 mil Dry	3.81	4.02	2.88	3.45
Sx O/D	83.8	94.2	85.1	89.6
% Voids	7.8	3.5	5.0	4.3

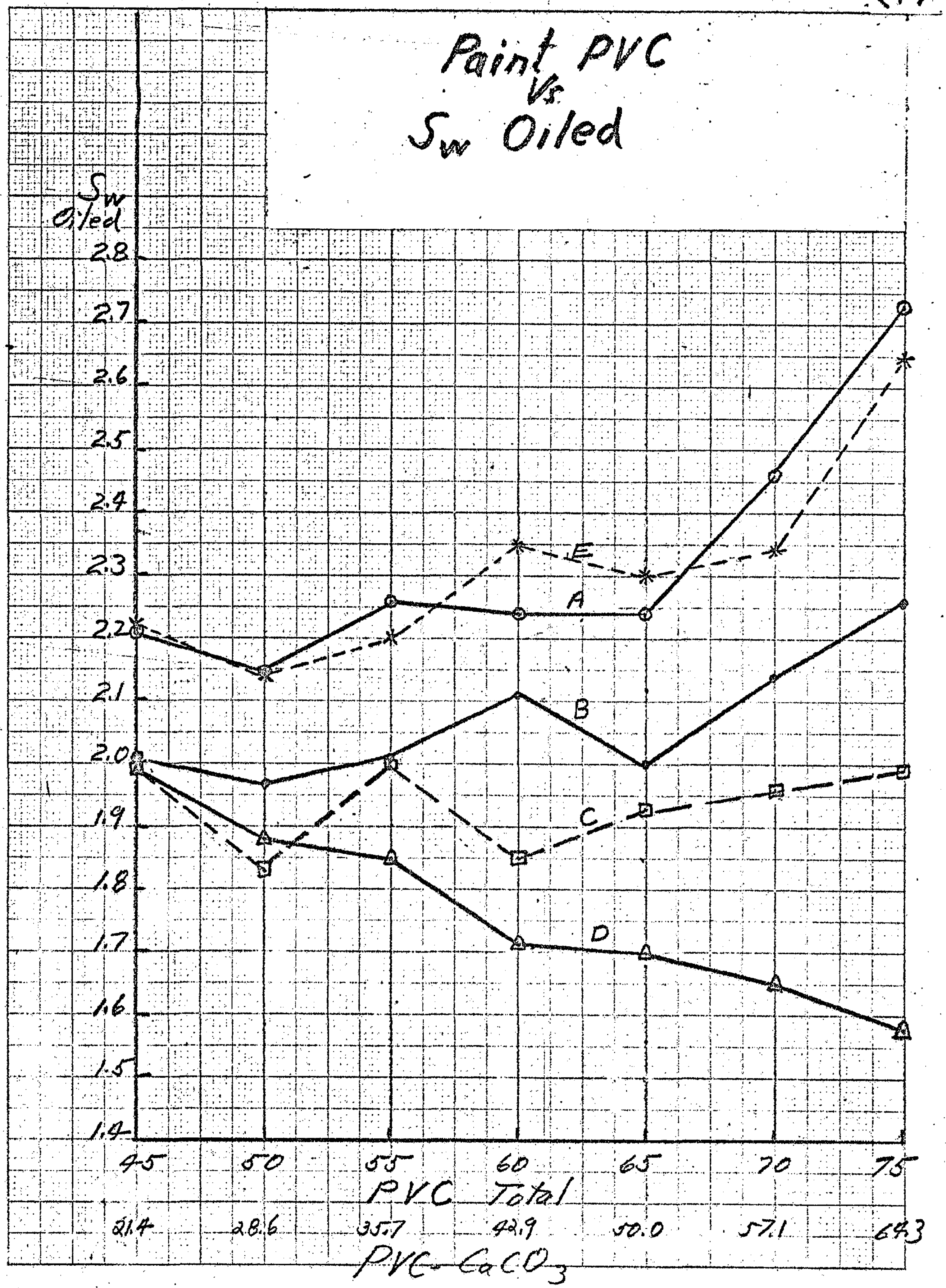

R-900 in alkyd flat vehicle
PVC Vs S_w & S_{1mil}
S_w – ⊙ .006", ⊗ .004"
S_{1mil} – • .006", + .004"
S_{1mil} S_w
5.8 4.0
3.8
5.4 3.6
3.4
5.0 3.2
3.0
4.6 2.8
2.6
4.2 2.4
2.2
3.8 2.0
1.8
3.4 1.6
1.4
3.0 1.2
10 15 20 25 30 35 40
S_{1mil} Flat vehicle
S_w-Gloss vehicle
S_w Flat Vehicle
PVC of R-900

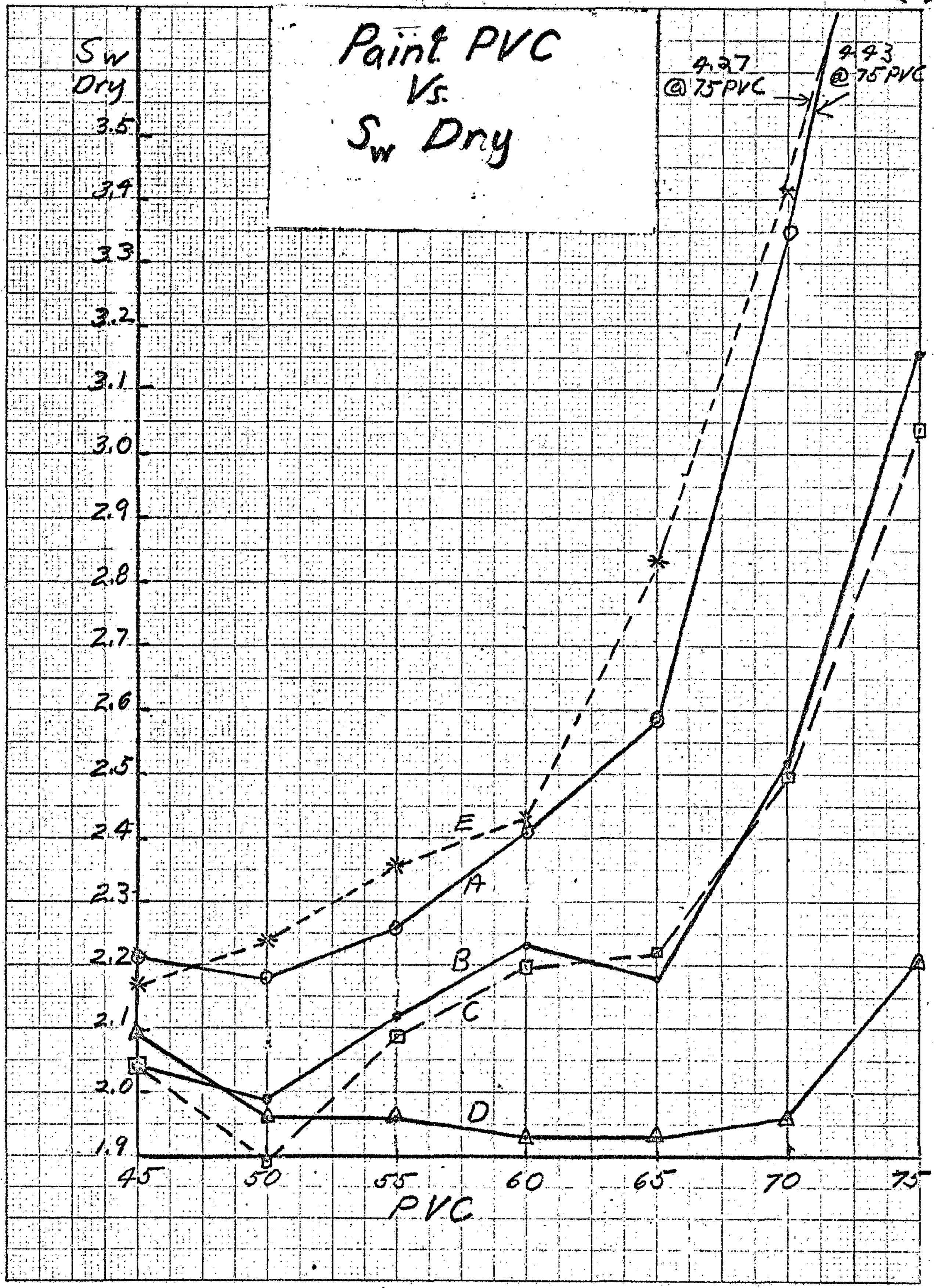
(2)


R-900+Camel White
PVC Free TiO_2 Vs.
Sw & S 1 mil
All 65 PVC
•, ×- Flat vehicle
⊙, ⊗- Gloss vehicle
S-1 mil dry
S-1mil oiled
Sw-oiled
Sw & S1mil
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
10
15
20
25
30
35
40
PVC Free TiO_2

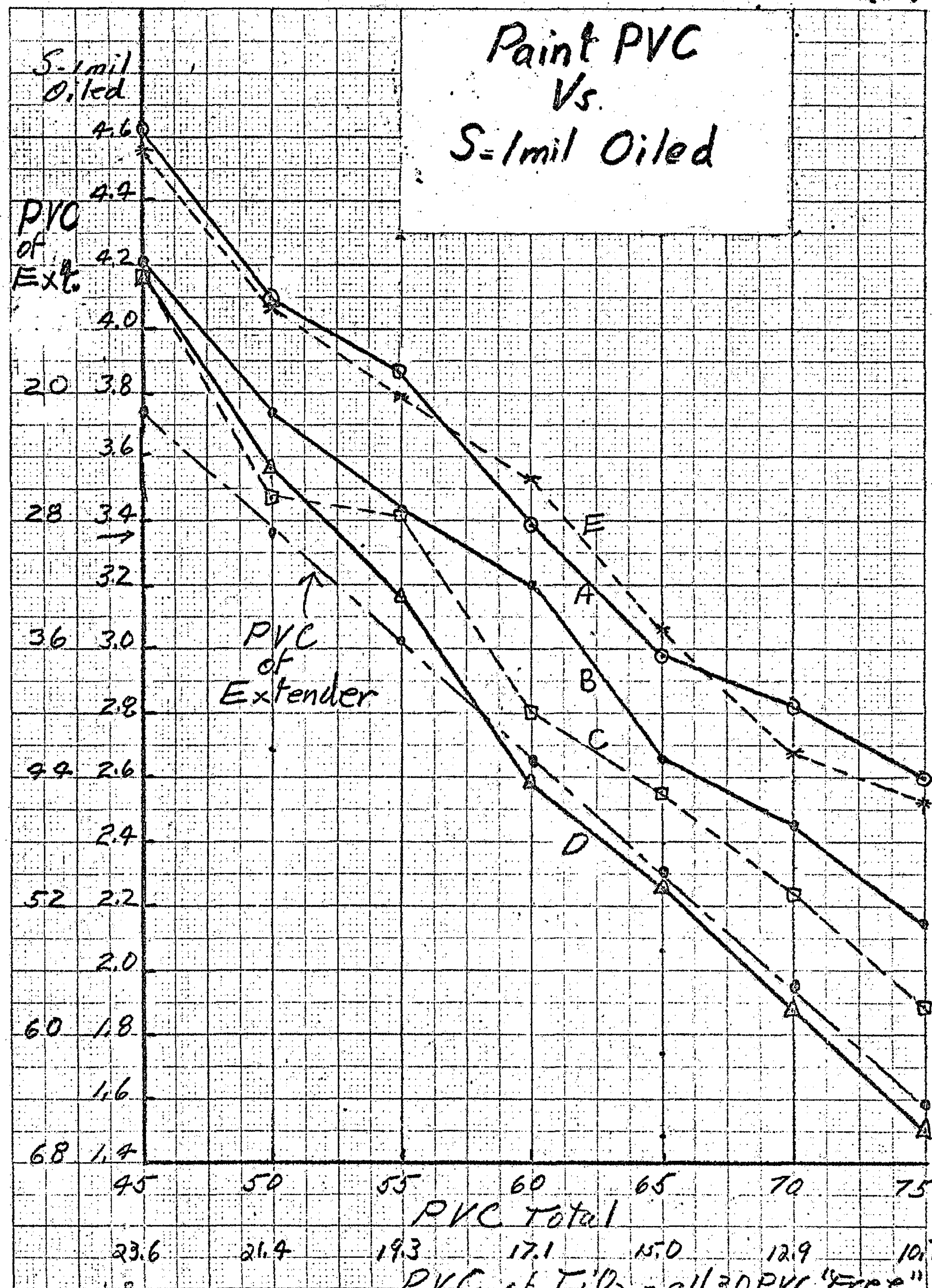


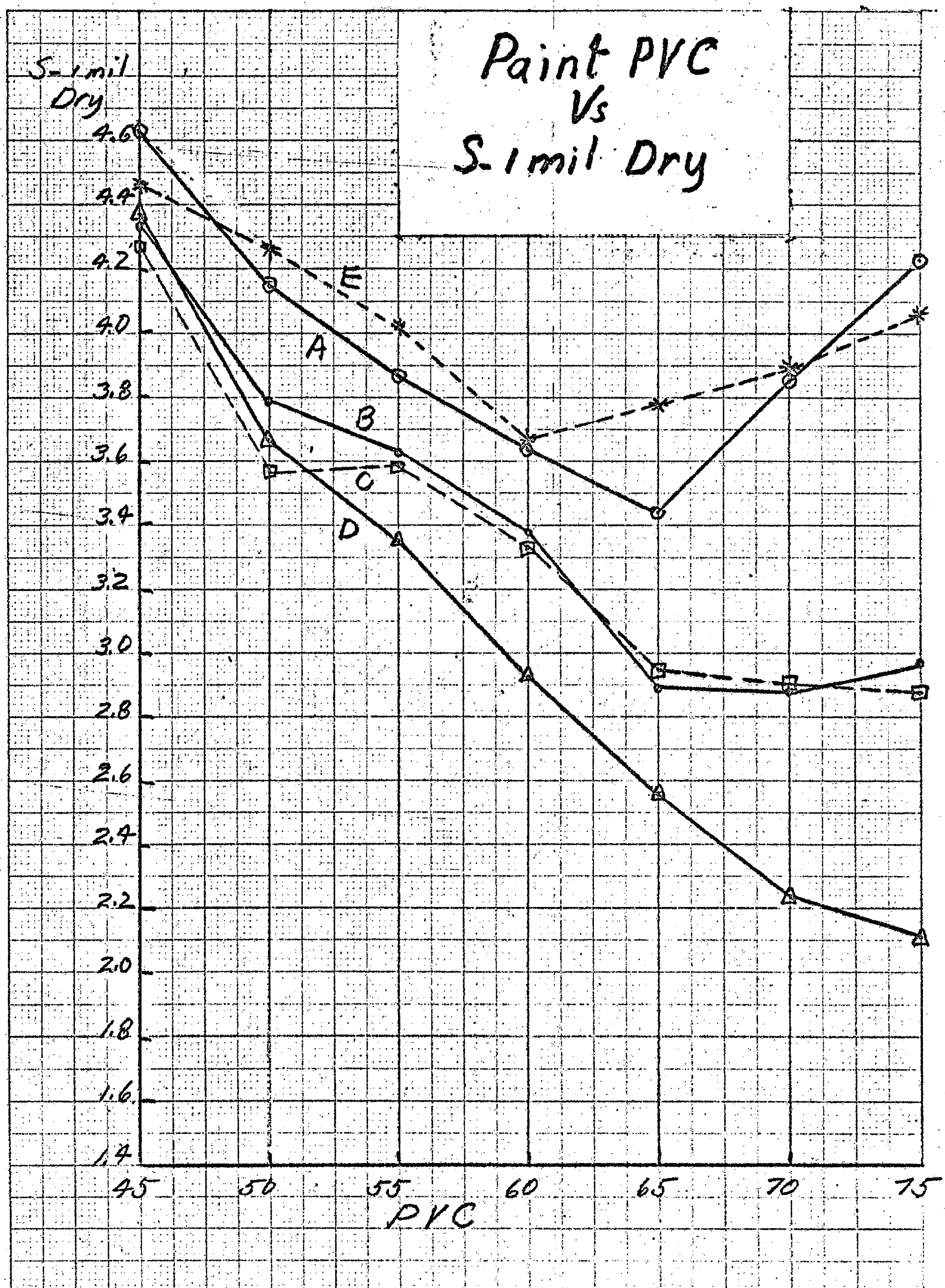
R-900 + Camel White
PVC Free TiO_2 Vs. Gloss
&
Effect of TiO_2 Packing
All 65 PVC
PVC
Extender PVC
minus 2x TiO_2 PVC
Gloss
Gloss vehicle
Flat vehicle
85° Gloss
Gloss vehicle
Flat vehicle
60° Gloss
-4.9 at
40 Free
TiO_2 PVC
Free TiO_2 PVC
10
15
20
25
30
35
40

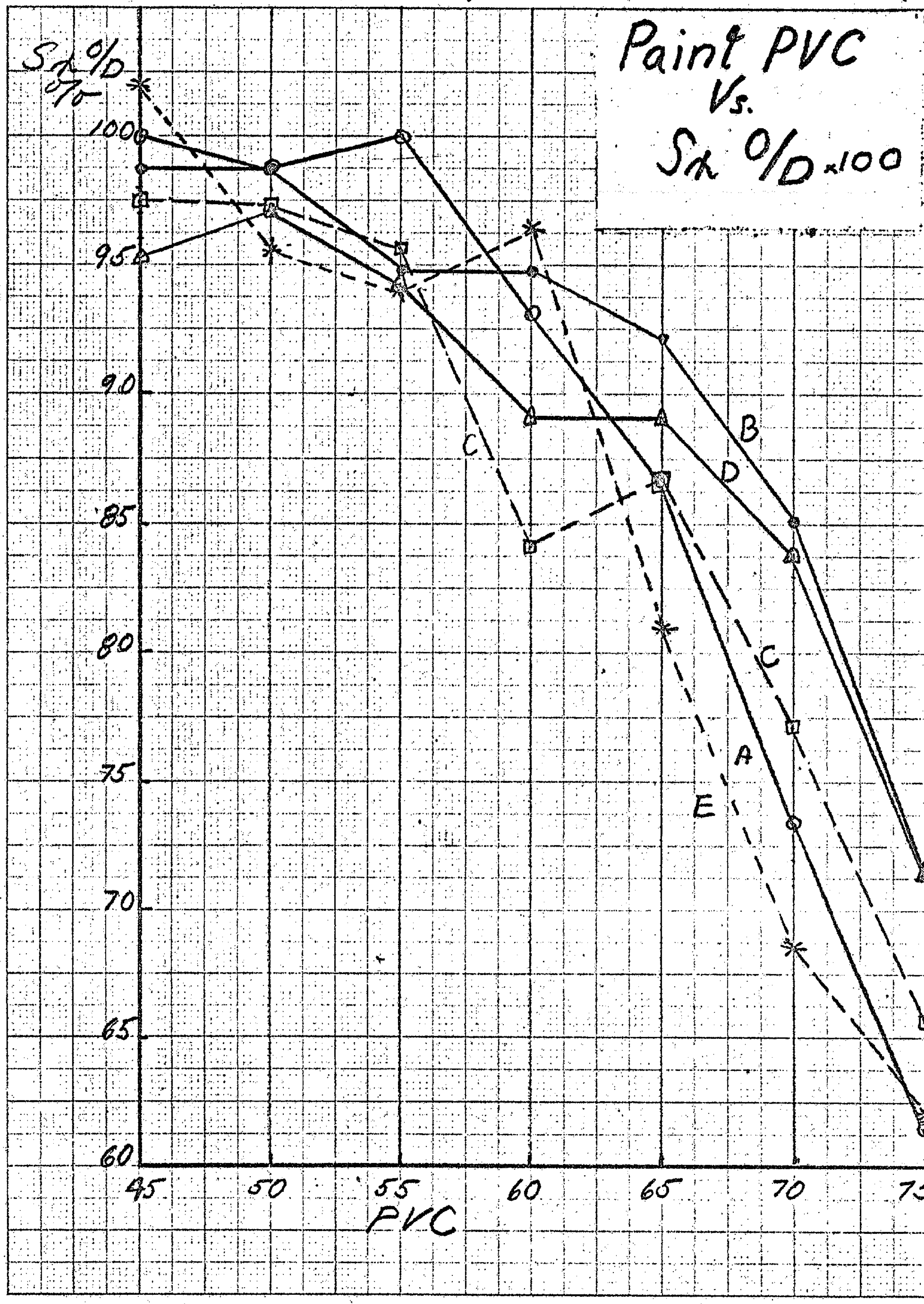

Paint PVC
Vs
Sw Oiled
Sw
Oiled
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
E
A
B
C
D
45
50
55
60
65
70
75
PVC Total
21.4
28.6
35.7
42.9
50.0
57.1
64.3
PVC - CaCO3

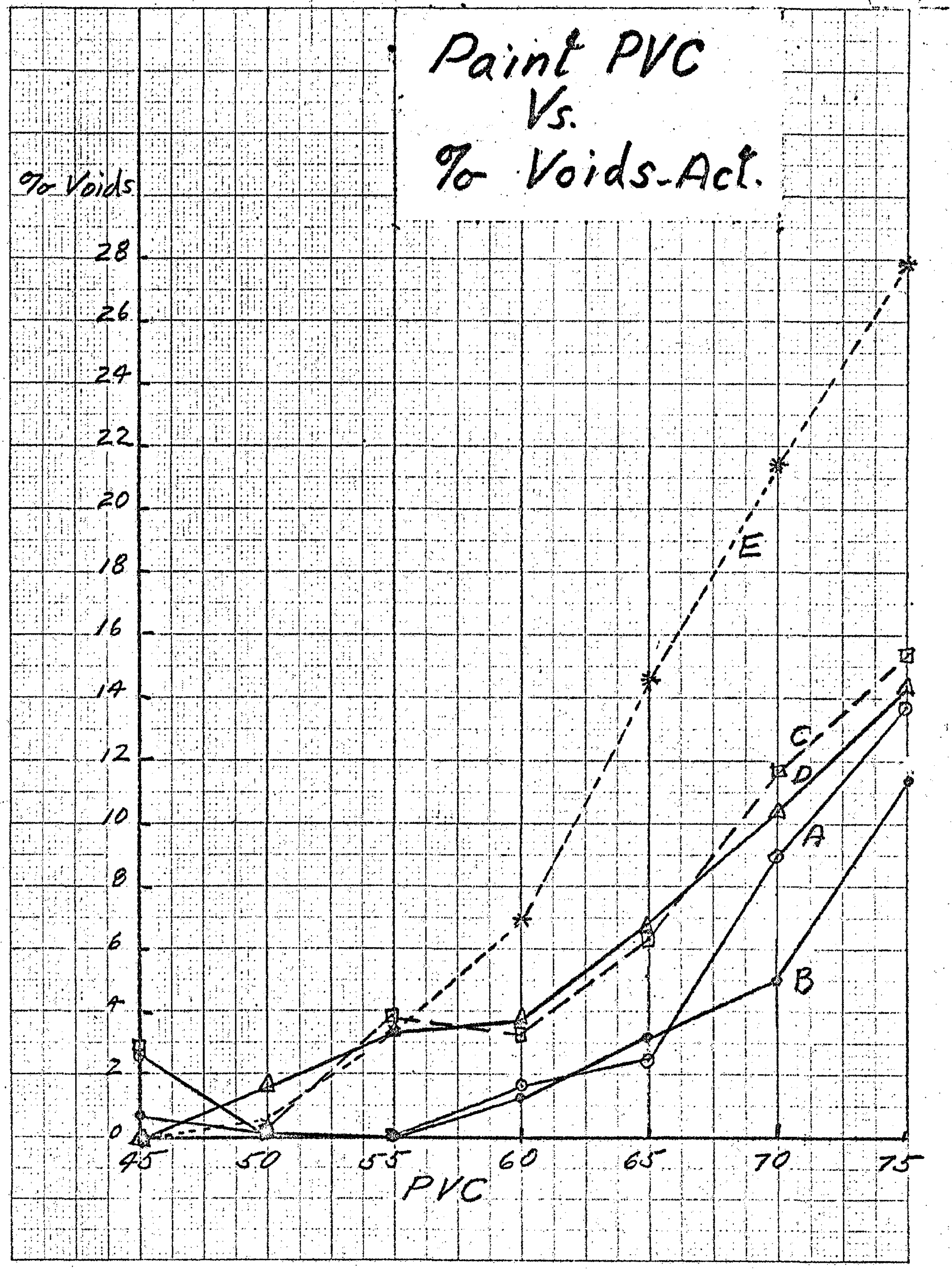


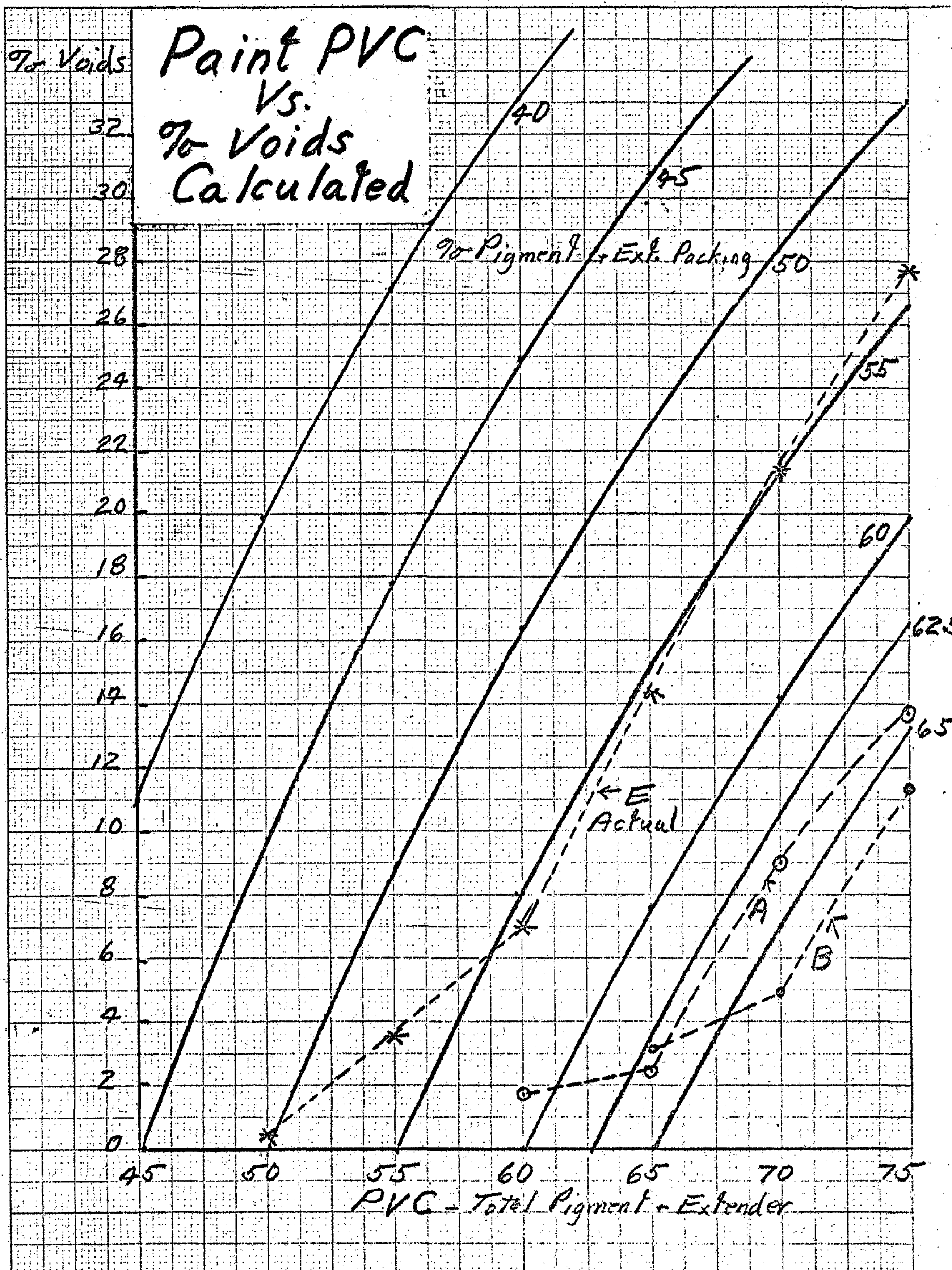
Paint PVC Vs. S_w Dry
S_w Dry
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
45
50
55
60
65
70
75
PVC
4.27 @ 75 PVC
4.43 @ 75 PVC
E
A
B
C
D


Paint PVC
Vs.
S=1mil Oiled
S-1mil
Oiled
PVC
of
Ext.
4.6
4.4
4.2
4.0
20 3.8
3.6
28 3.4
3.2
36 3.0
2.8
44 2.6
2.4
52 2.2
2.0
60 1.8
1.6
68 1.4
PVC
of
Extender
E
A
B
C
D
45
50
55
60
65
70
75
PVC Total
23.6
21.4
19.3
17.1
15.0
12.9
10.7
PVC of TiO_2 - all 30 PVC "Free"


Paint PVC
Vs
S-1mil Dry
S-1mil
Dry
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
45
50
55
60
65
70
75
PVC
A
B
C
D
E


Paint PVC
Vs.
Sn O/D ×100
Sn O/D %
100
95
90
85
80
75
70
65
60
45
50
55
60
65
70
75
PVC
A
B
C
C
D
E


Paint PVC
Vs.
% Voids-Act.
% Voids
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
45
50
55
60
65
70
75
PVC
E
C
D
A
B



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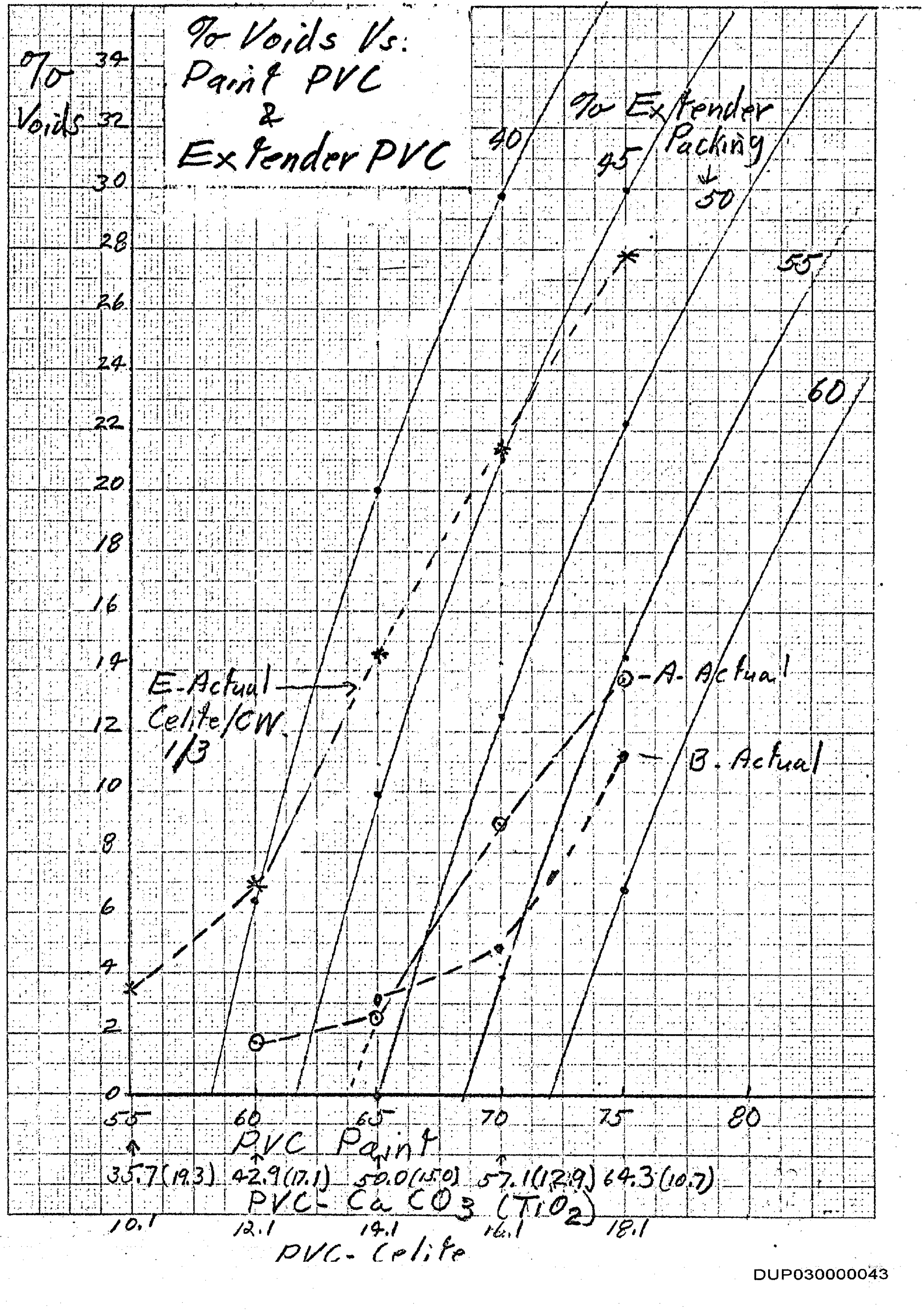
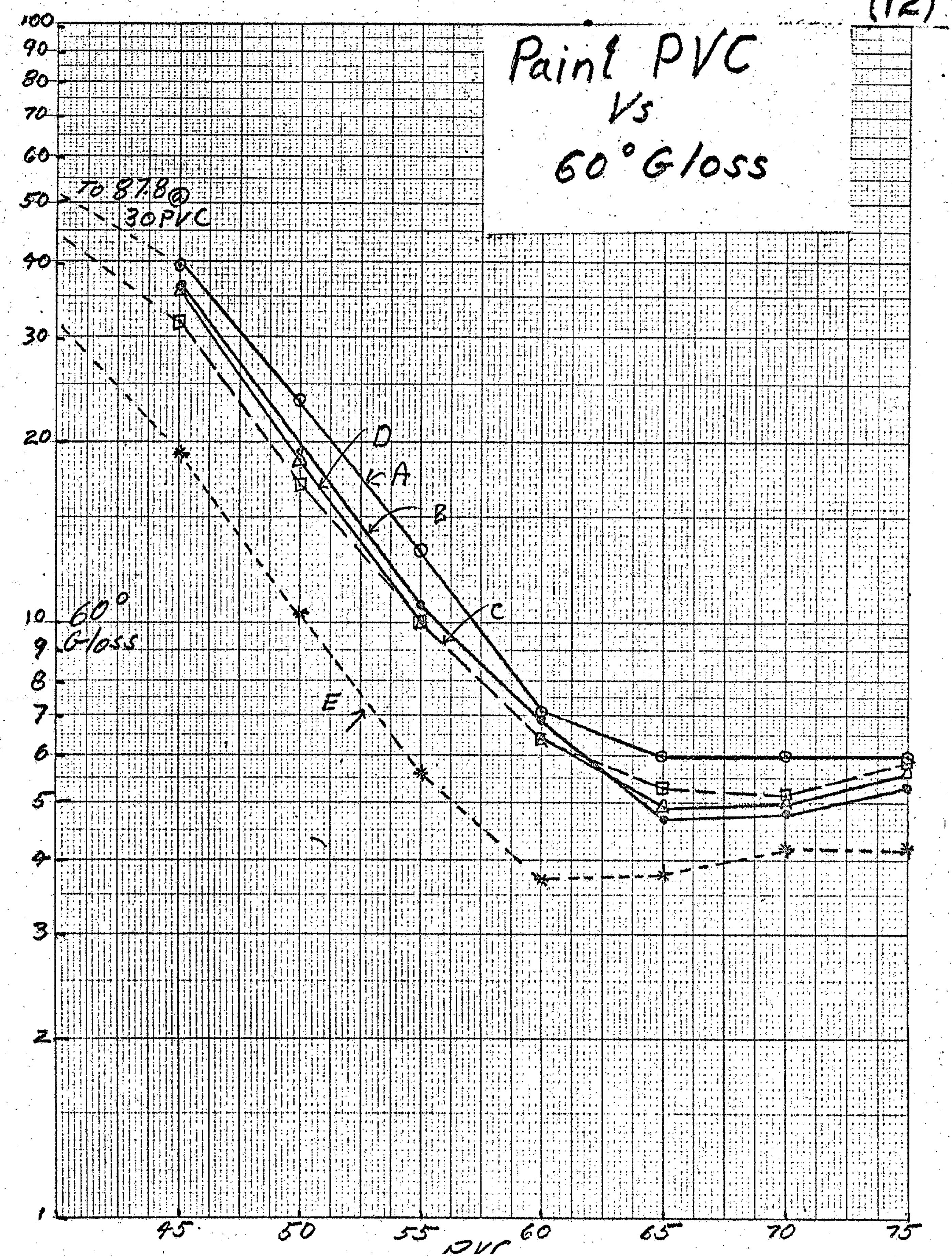
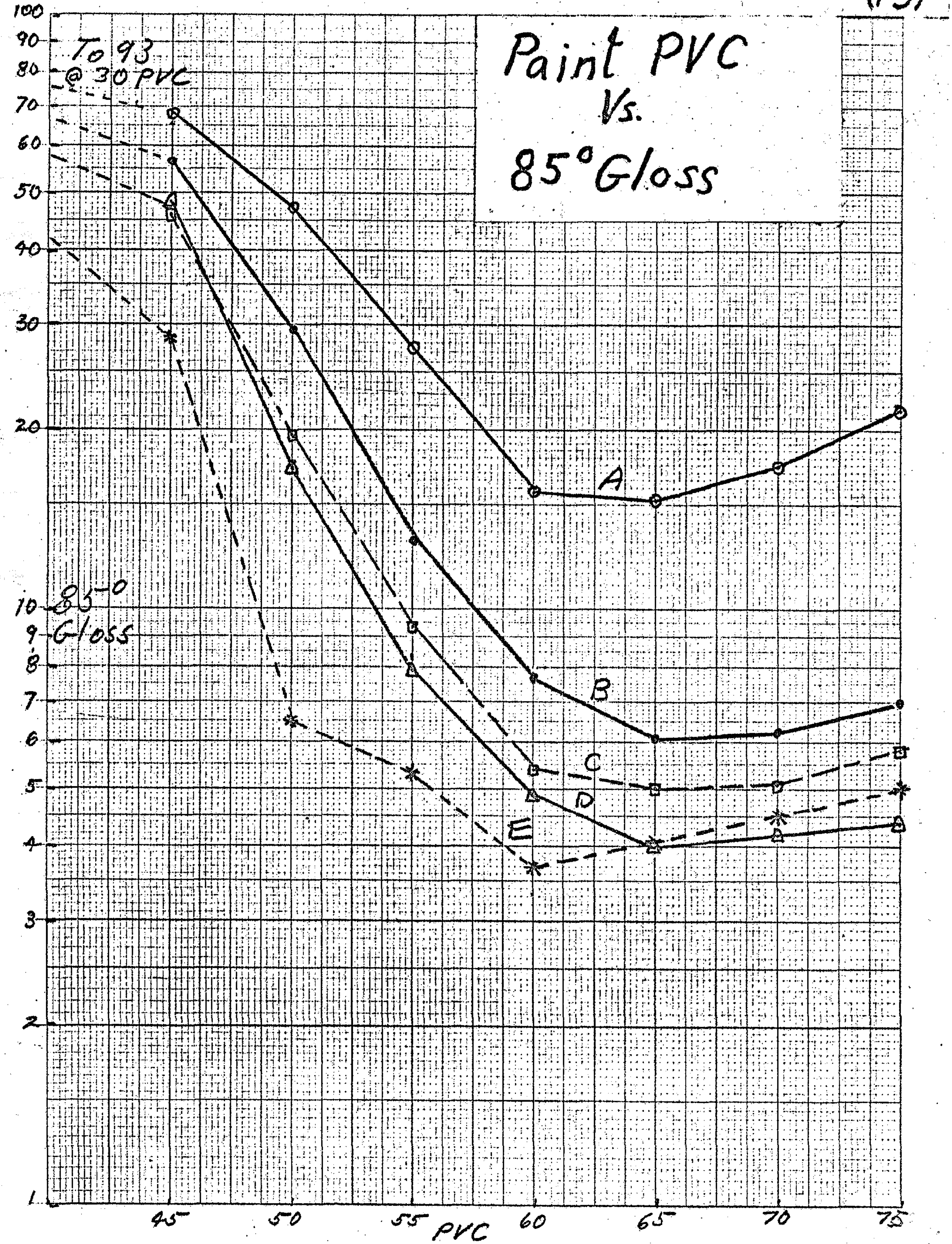
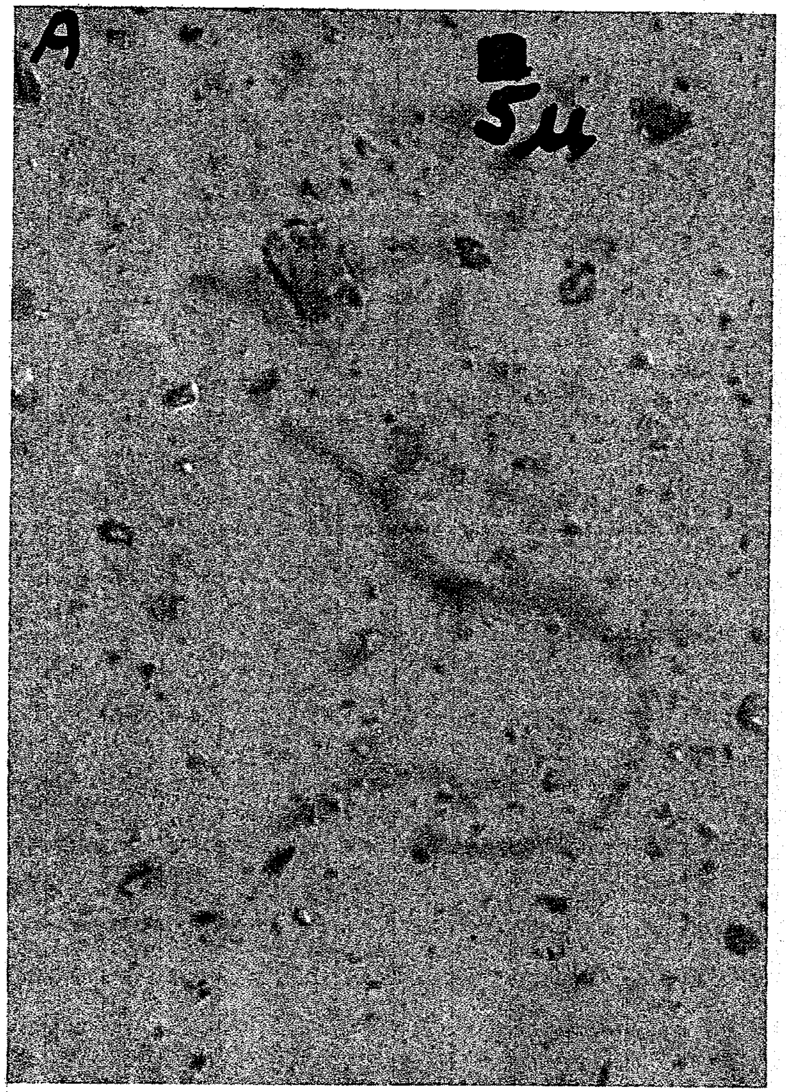

% Voids Vs: Paint PVC & Extender PVC
% Voids
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
% Extender Packing
40
45
50
55
60
E-Actual Celite/CW 1/3
-A- Actual
B. Actual
55
60
65
70
75
80
PVC Paint
35.7 (19.3)
42.9 (17.1)
50.0 (15.0)
57.1 (12.9)
64.3 (10.7)
PVC- Ca CO3 (TiO2)
10.1
12.1
14.1
16.1
18.1
PVC- Celite


Paint PVC
Vs
60° Gloss
TO 87.8 @ 30 PVC
60° Gloss
A
B
C
D
E
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
45
50
55
60
65
70
75
PVC

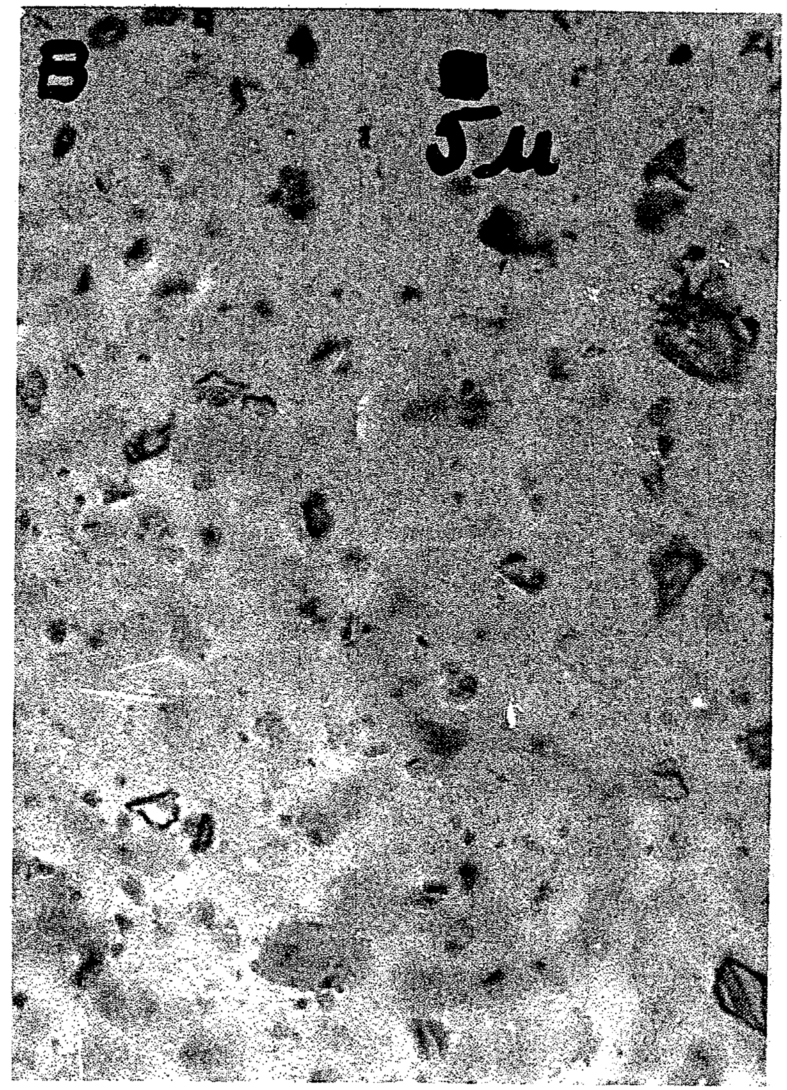

Paint PVC
Vs.
85° Gloss
To 93
@ 30 PVC
85°
Gloss
A
B
C
D
E
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
45
50
55
60
65
70
75
PVC

P-1

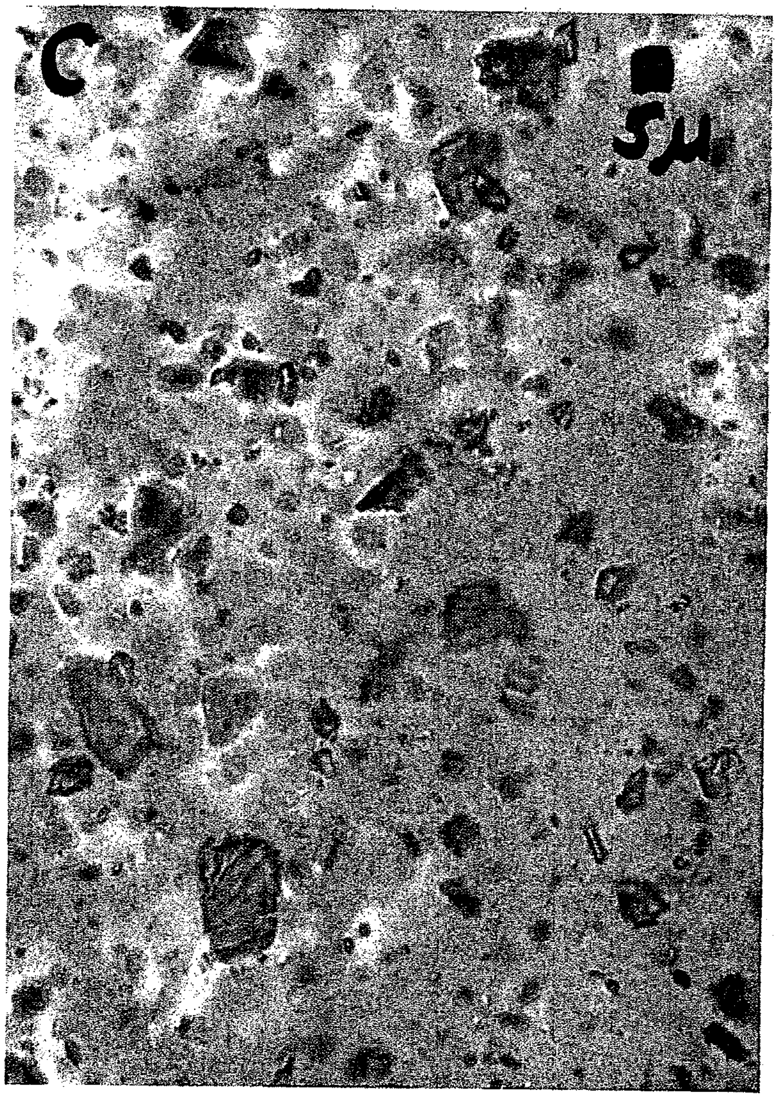
Camel White



Camel Tex



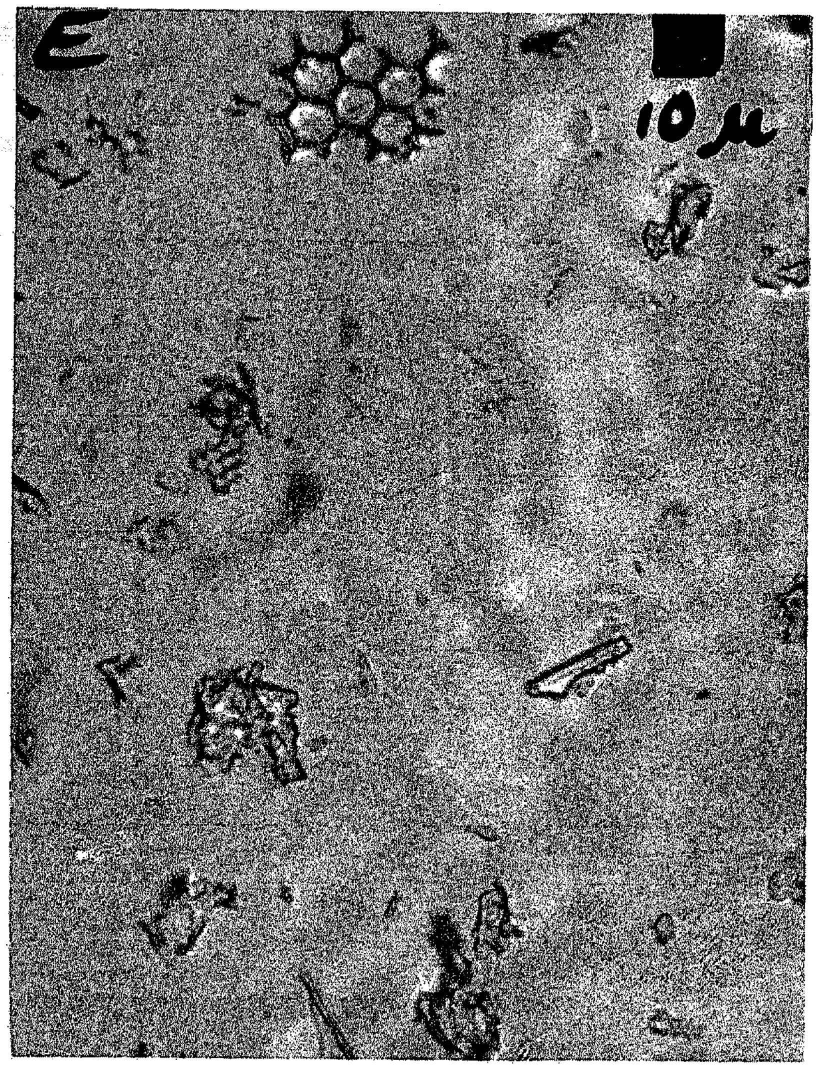
Camel Carb



#10 White

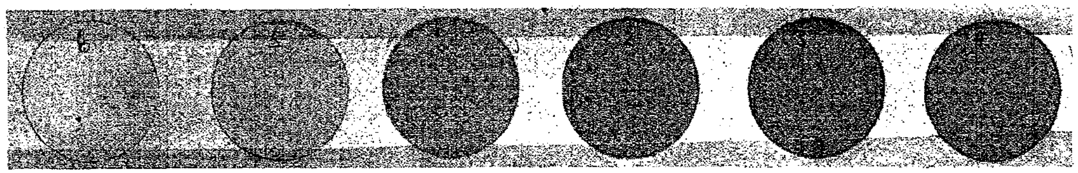
P-2

Celite #281

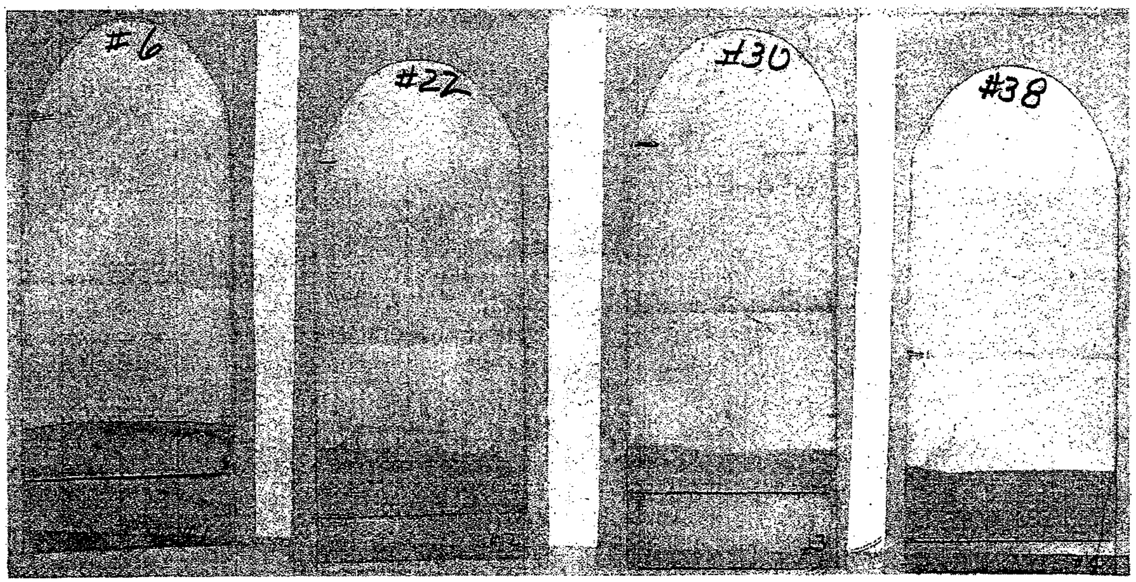


Black Oil Paste Stain

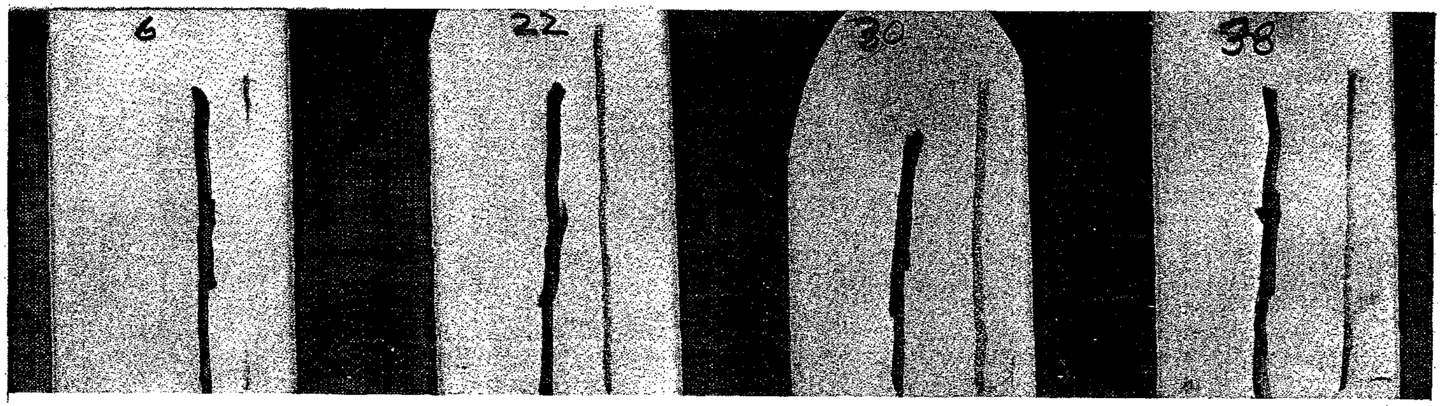
Enamel alone | Enamel Stain | 70 PVC Flats #6 | 70 PVC Flats #22 | 70 PVC Flats #30 | 70 PVC Flats #38



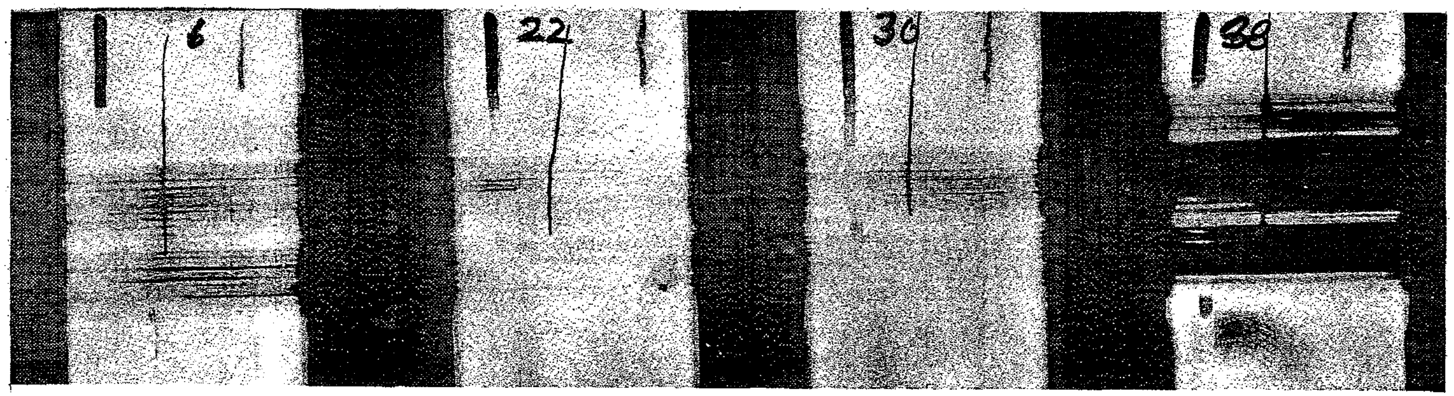
Brush Polished



Mercurochrome Stain



1000 ~ Brush - Soap soln.



1000 ~ Brush - Ajax slurry
Bottom - Ajax on cloth - by hand

P-5