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The Effect of Relative Sediment Volume on Sheet Properties of Coated Paper

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By

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Abstract:

The degree of dispersion of pigment has been claimed to be an important variable in the determination of sheet properties such as smoothness and gloss. The degree of dispersion of a pigment can be related to relative sediment volume (RSV) by comparison of the solid and void volumes of a clay slip. One school of thought suggests that there is a relation between RSV and coated sheet properties; this relation being, as RSV decreases, smoothness and gloss increase. It was decieded that an attempt to relate RSV (degree of dispersion) to optical properties of coated paper could be valuable. Because it was difficult to measure RSV of a coating color using the centrifuge method, it was assumed that if a constant amount of adhesive was used in each of the clay slurries with different RSVs, the relative RSVs of the coating color would remain constant. The theoretical RSVs of the respective coatings were plotted against the optical properties of the coated paper. No correlation was found between RSV and smoothness, gloss, brightness, or opacity, although it was found that as the percent electrolyte added was increased, the gloss increased.

TABLE OF CONTENTS

PAGE

INTRODUCTION..... 1

BACKGROUND AND DEVELOPMENT
OF THE PROBLEM..... 1

ASSUMPTION MADE..... 2

EXPERIMENTAL DESIGN..... 3

TESTS PERFORMED ON THE COATED PAPER..... 3

DISCUSSION..... 4

RELATION BETWEEN RELATIVE SEDIMENT VOLUME
AND SHEET PROPERTIES..... 5

CONCLUSIONS..... 14

Background:

Many paper mills are coating paper to instill properties such as high smoothness, gloss, brightness, and opacity to a sheet of paper. It has been desired in the paper industry to relate a property of coating such as relative sediment volume (RSV) to sheet properties of coated paper. No literature was found relating RSV and coated sheet properties although much work has been done with RSV (degree of dispersion).

It has been said that the gloss and smoothness of a sheet of coated paper reflect the degree of dispersion of pigments at the time the coating is applied to a sheet of paper.[1] This degree of dispersion is related to the term RSV. RSV is the ratio between sediment volume of a pigment system and its solids content. Sediment volume is the volume occupied by the solids plus the volume of the voids in a coating. Since RSV is independent of particle size but is dependent upon degree of dispersion or flocculation of a system, one can conclude that the RSV of a coating color will be large if the particles of the system agglomerate causing a large void volume in the coating. It will be noted that the dispersion of an agglomerated system will result in the reduction of the sediment volume and therefore a reduction in RSV. Dispersion of an agglomerated system would be similar to changing a large particle system to one of small particles. It has been the thought of many that by decreasing the size of the pigment particles, an increase in smoothness, gloss and sheet properties would result. Since it was impossible to find data relating RSV to sheet properties of coated paper, it was decieded that an attempt should be made to relate RSV to sheet properties such as smoothness, opacity, gloss, and brightness.

The normal procedure of measuring RSV of a coating color is to place the sample of coating into graduated centrifuge tubes and run the centrifuge for one hour at 2000 revolutions per minute. According to Moore[2] RSV does a good job on clay-water systems but is completely unusable in solids levels greater than 50% and at adhesive levels greater than 5 parts per hundred (pph). Since 5 pph adhesive would not be a good representation of the amount of adhesive used in coating colors in the paper industry, a method by which one could estimate RSV of coating with 15 pph adhesive had to be devised. It was assumed that if 15 pph adhesive was added to sample A of clay with RSV A' and 15 pph adhesive was added to sample B of clay with RSV B', then the relative RSVs of the two coating would remain constant. The final coating color is a mixture of two very complex colloidal systems, that of clay water mixture and the colloidal system of adhesives. It was assumed that if a constant amount of adhesive was added to different clay water mixtures that the colloidal system of adhesives would remain constant and not affect the theoretical RSV of the clay. After this assumption was made, a way of estimating the RSV of a coating color system was readily available.

A kaolin system of predetermined RSV with different degrees of dispersion was used. It was decided to vary the amount of electrolyte added keeping time and rate of agitation constant, amount of starch added constant, in fact an attempt was made to hold everything constant except for the amount of dispersing agent added. The percent electrolyte added was then converted to RSV values by using graphs, based on the work by Kline[3], of RSV versus percent electrolyte added in the original deionized clay and water system.

Experimental Design:

Into a container was placed 300 grams of 37% solids deionized clay of predetermined RSV. This mixture of deionized water and clay was placed in a high speed mixer (Hamilton Beach) along with 15.75 grams of 88% solids Stayco S starch and a given percentage of NaOH which varied from 0 to 2.1% added for the respective systems. This mixture was then subject to high agitation, while still cold, in the Hamilton Beach for a period of 400±10 seconds. This operation insured complete and uniform blending of the pigment and starch before the cooking of the starch was begun. In order to convert the starch without lowering the solids of the coating color, the starch was cooked in the clay-water system. The blender and mixture were then placed in a constant temperature bath (80±3°C) with low agitation for 900±10 seconds. The rate of agitation was kept low while cooking the starch because a high rate of agitation would cause a vortex to form forcing air into the system. This air would be trapped in the converted starch system. After cooking pH, Hercules rheograms and brookfield viscosity were determined. These three operations usually took seven to ten minutes to perform, and the coating was immediately applied to the sheet of conditioned paper using #11 drawdown rod. The coating was then air dried. Prior to coating, the paper had been conditioned to constant temperature and humidity. Excess samples of each coated paper were made in order to insure that at least 5 samples of 9 1 pound coat weight for 25 x 38 - 500 ream size could be tested for the following sheet properties:

1. smoothness; Tappi Standard-T479
2. opacity; Tappi Standard-T425
3. brightness; Tappi Standard-T452
4. gloss; Tappi Standard-T424

The five samples to be tested of each group were determined by weighing and were tested for smoothness, brightness, opacity, and gloss. The coated sheets, each 7 x 5 inches, were then supercalendered with 40 pounds per square inch pressure in 2 nips and tested, then supercalendered with 2 more nips (4 nips total) and tested for the four sheet properties. In each case the test was run in the center of the sample and under the same conditions so that a comparison could be made. The supercalendering was done on the laboratory calender at Western Michigan University, Department of Paper Technology.

Discussion:

After determining the RSVs of each coating color from the known amount of % NaOH added and predetermined graphs, and determining the sheet properties for the respective RSVs (tables-I through IV), RSVs were plotted against smoothness, opacity, gloss and brightness for zero, two, and four nips in the supercalender. No correlation between RSV and these four sheet properties could be found as can be seen from figures one through four.

It is evident that as one decreases the size of clay particles (same effect as dispersing pigments or lowering RSV) that are applied to a sheet of paper, the valleys are going to be more uniformly filled in and one should get a smoother and more glossy sheet of coated paper. If one applied a coating that has large particles or a large degree of agglomeration of particles to a sheet of paper it can be theorized that these larger particles would not form as smooth a surface as smaller or more dispersed particles would because the larger particles would not fit as closely together as the smaller particles. Thus the smaller the particle agglomeration, the better the gloss should be in a sheet of coated paper.

Results of this investigation indicate that RSV (degree of agglomeration) has no correlation to gloss or smoothness. Although no correlation could be found between RSV and sheet properties there was a definite correlation between % electrolyte added and gloss (figure 4A). Tests were run in order to try to explain this relation between % electrolyte added and gloss, and that is as % electrolyte added increases, the gloss increases. The degree of dispersion of a clay slip with respect to the % NaOH added reaches a maximum around .4% NaOH and then above this amount there is an increase in flocculation with increased addition of electrolyte. With increased flocculation one would expect the gloss to decrease; an increase in gloss was observed with an increase in % NaOH above .4%.

Determination of Denison Wax pick revealed that as gloss increased, wax pick indicated a downward trend (figure 4A) and as wax pick decreased, gloss increased. These relationships were found in the range of pH below 7. This evidence along with the fact that K N ink receptivity decreased as wax pick increased indicated that the adhesive was staying in the coating, (table V) but the wax picks indicated the adhesive was not binding at a pH below 7. Investigation of the problem revealed that acid hydroylysis of the starch below a pH of seven was causing the starch to be converted to something rather than an adhesive. It was in the region of pH 7 or below that most fluccuation in % NaOH versus gloss occured. Above pH 7 the gloss increased with an increased amount of electrolyte added, which was unable to be explained.

TABLE-I GLOSS

RSV	0-NIPS	2-NIPS	4-NIPS
3.37	3.95	35.88	40.00
3.37	5.58	40.80	48.72
2.86	3.55	28.60	34.15
2.36	5.54	29.26	33.44
2.38	4.34	29.76	31.32
2.37	5.72	33.22	38.74
2.47	6.06	32.46	38.28
2.58	7.26	33.66	41.48
2.56	10.40	44.18	49.15
2.65	10.02	45.16	50.86

TABLE-II OPACITY

RSV	0-NIPS	2-NIPS	4-NIPS
3.37	92.9	92.9	92.0
3.37	93.1	92.7	92.4
2.86	93.8	92.9	92.0
2.36	93.6	92.3	91.5
2.38	92.5	92.2	91.2
2.37	93.3	91.9	91.4
2.47	92.8	91.6	91.9
2.58	93.6	92.2	91.9
2.56	93.9	93.0	92.2
2.65	93.6	92.6	92.2

TABLE -III BRIGHTNESS

RSV	0-NIPS	2-NIPS	4-NIPS
3.37	80.9	79.7	79.1
3.37	81.5	79.3	78.7
2.86	80.1	78.7	76.7
2.36	79.3	78.2	77.9
2.38	79.3	78.0	77.6
2.37	79.3	78.1	77.7
2.47	80.3	78.2	77.8
2.58	79.6	78.5	77.7
2.56	79.4	77.7	77.8
2.65	79.1	77.9	77.4

TABLE-IV SMOOTHNESS

RSV	0-NIPS	2-NIPS	4-NIPS
3.37	29.3	55.7	57.7
3.37	33.0	55.5	65.4
2.86	27.6	44.1	49.7
2.36	34.4	46.6	50.6
2.38	28.3	50.0	53.1
2.37	31.0	54.9	59.6
2.47	30.3	56.2	62.5
2.58	34.0	44.7	60.4
2.56	37.5	55.3	59.8
2.65	34.9	60.6	58.7

TABLE-V

4-NIPS

%NAOH	WAX PICK	GLOSS	K+N INK
0	1	40.00	45.1
.06	0	48.72	44.8
.11	2	34.15	42.7
.22	2	33.44	40.3
.33	3	31.32	37.6
.55	2	38.74	40.9
.77	4	38.28	40.2
1.10	4	41.48	34.9
1.50	5	49.15	36.8
2.10	5	50.86	37.8

FIGURE-I

GLOSS VS. RSV

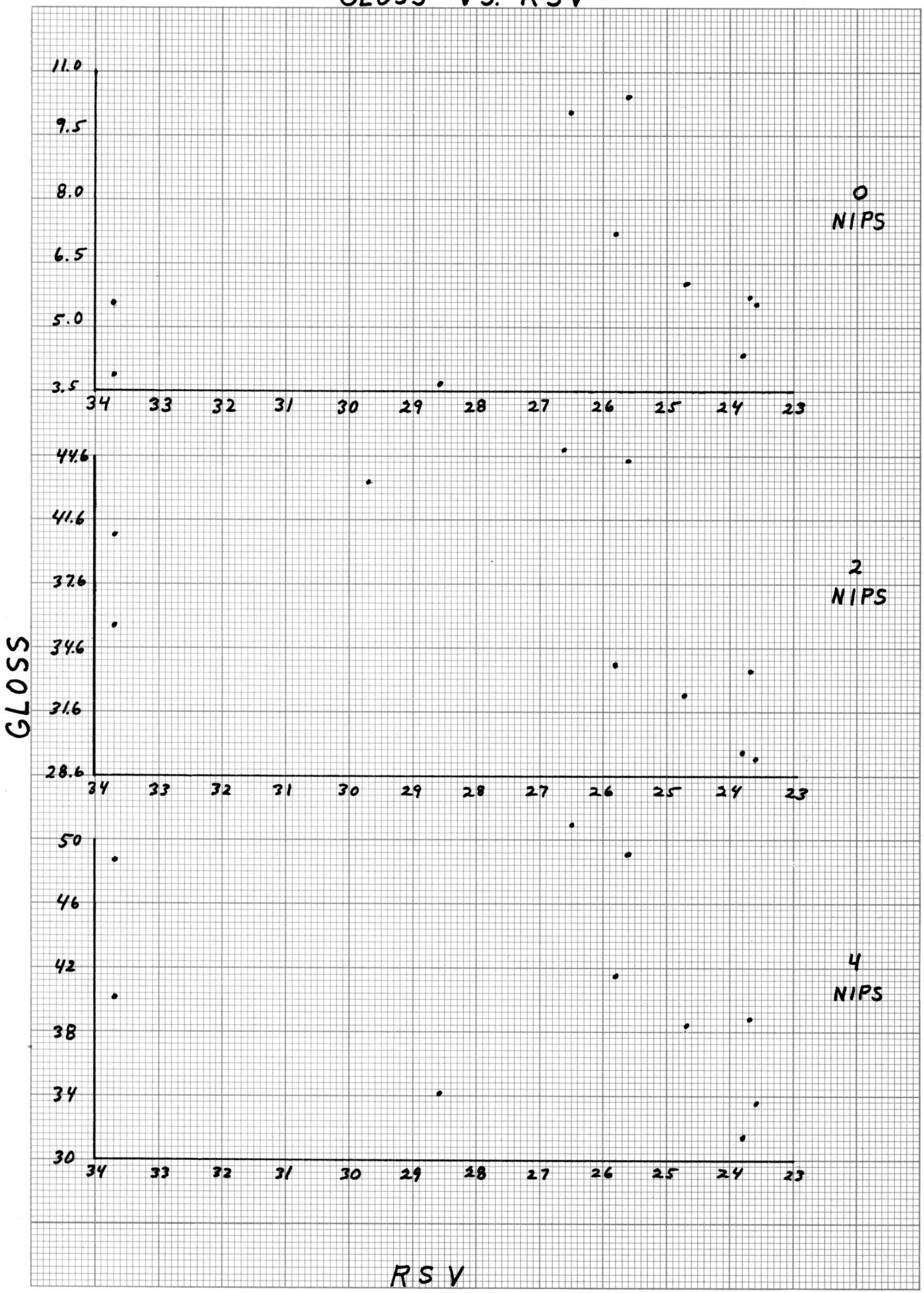


FIGURE-2

SMOOTHNESS VS. RSV

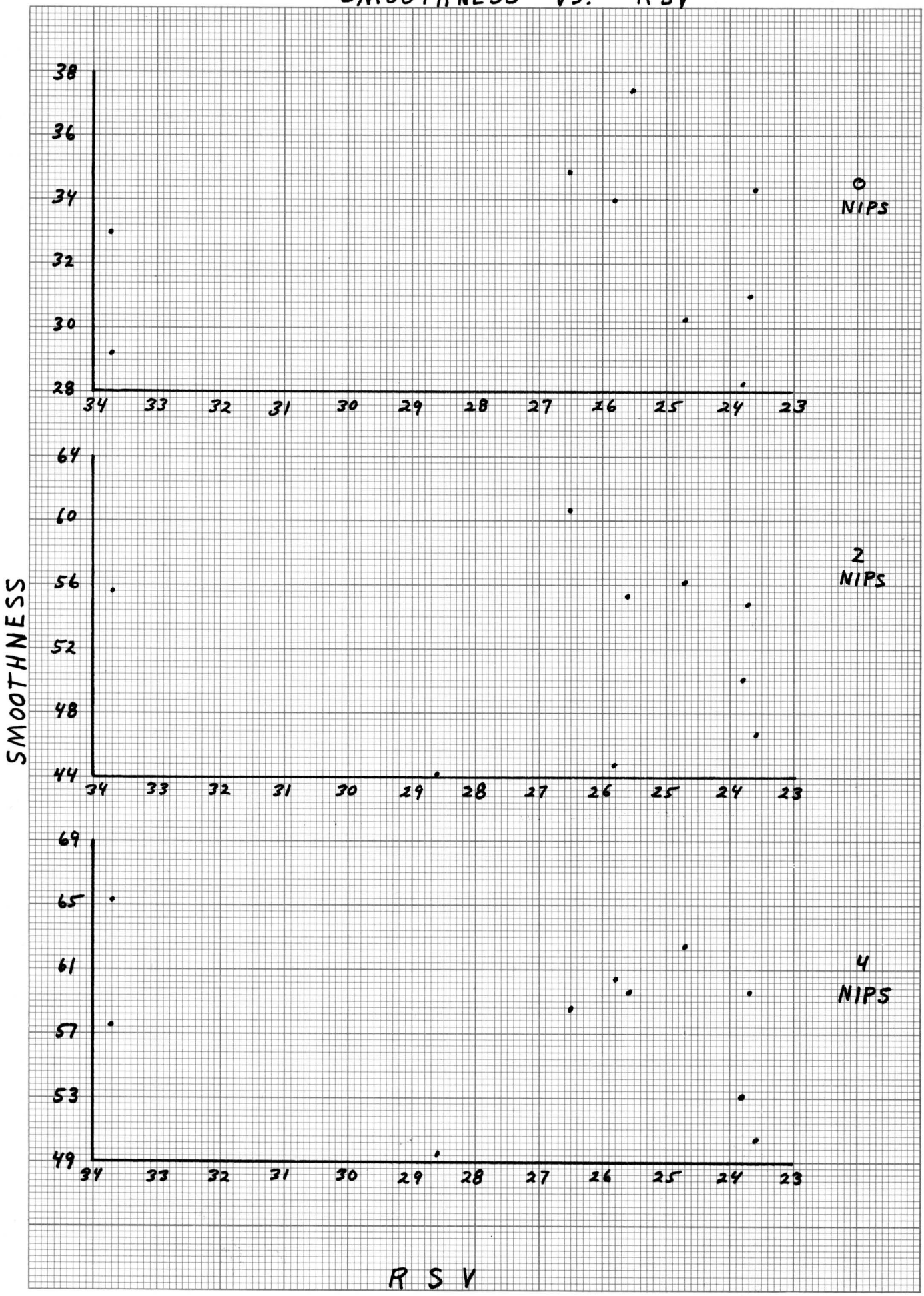


FIGURE - 3.

BRIGHTNESS VS. RSV

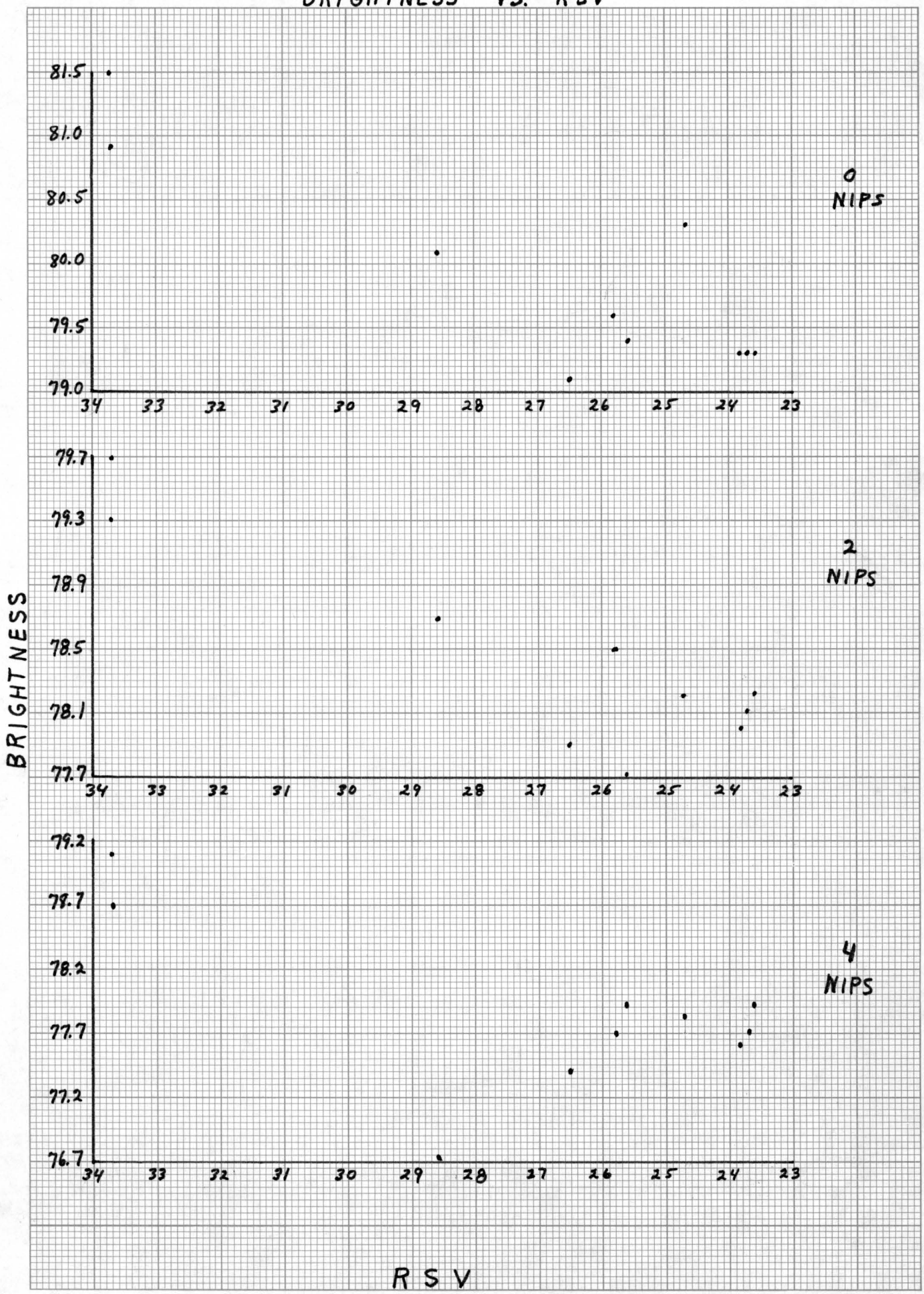


FIGURE-4.

OPACITY VS. RSV

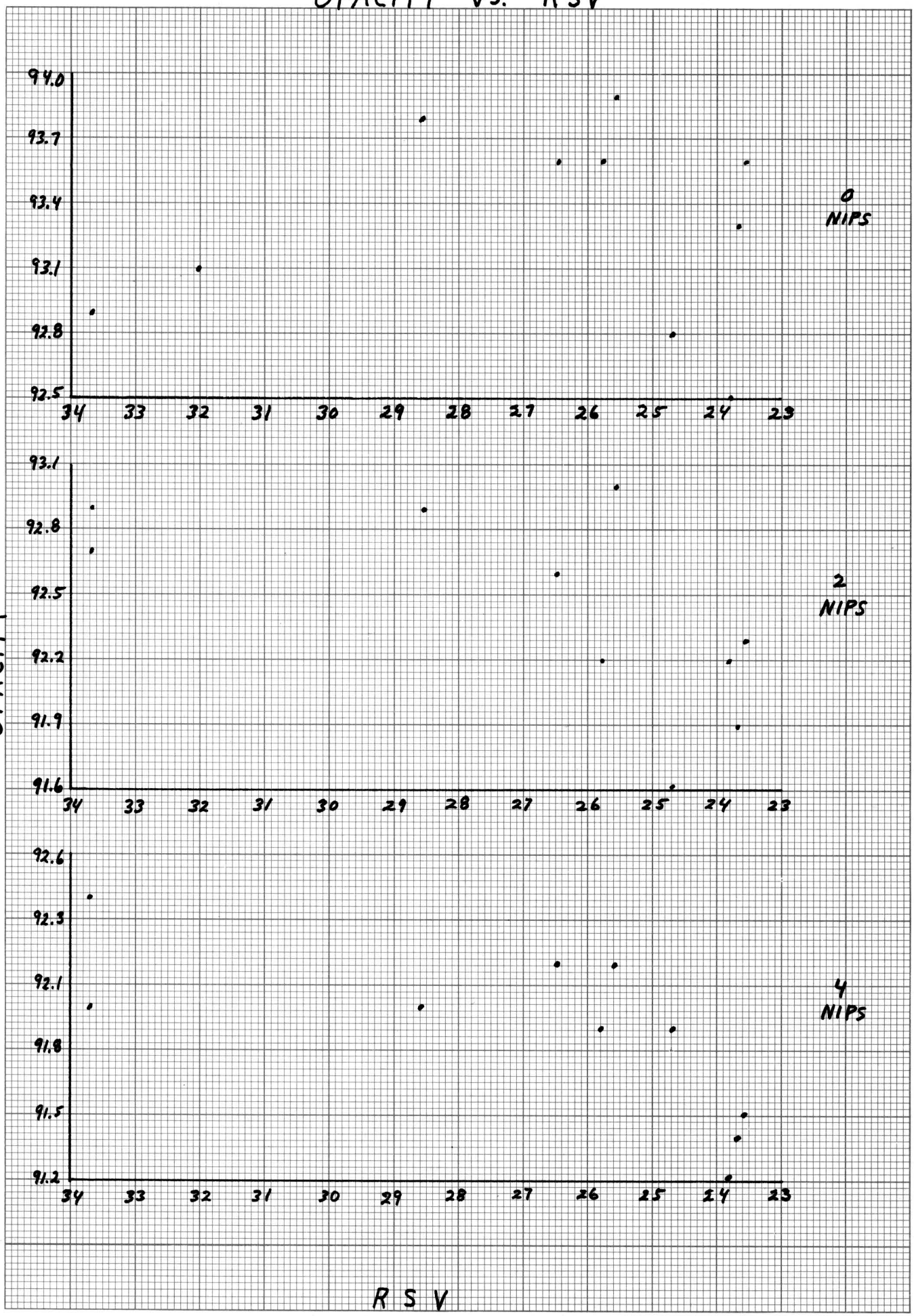
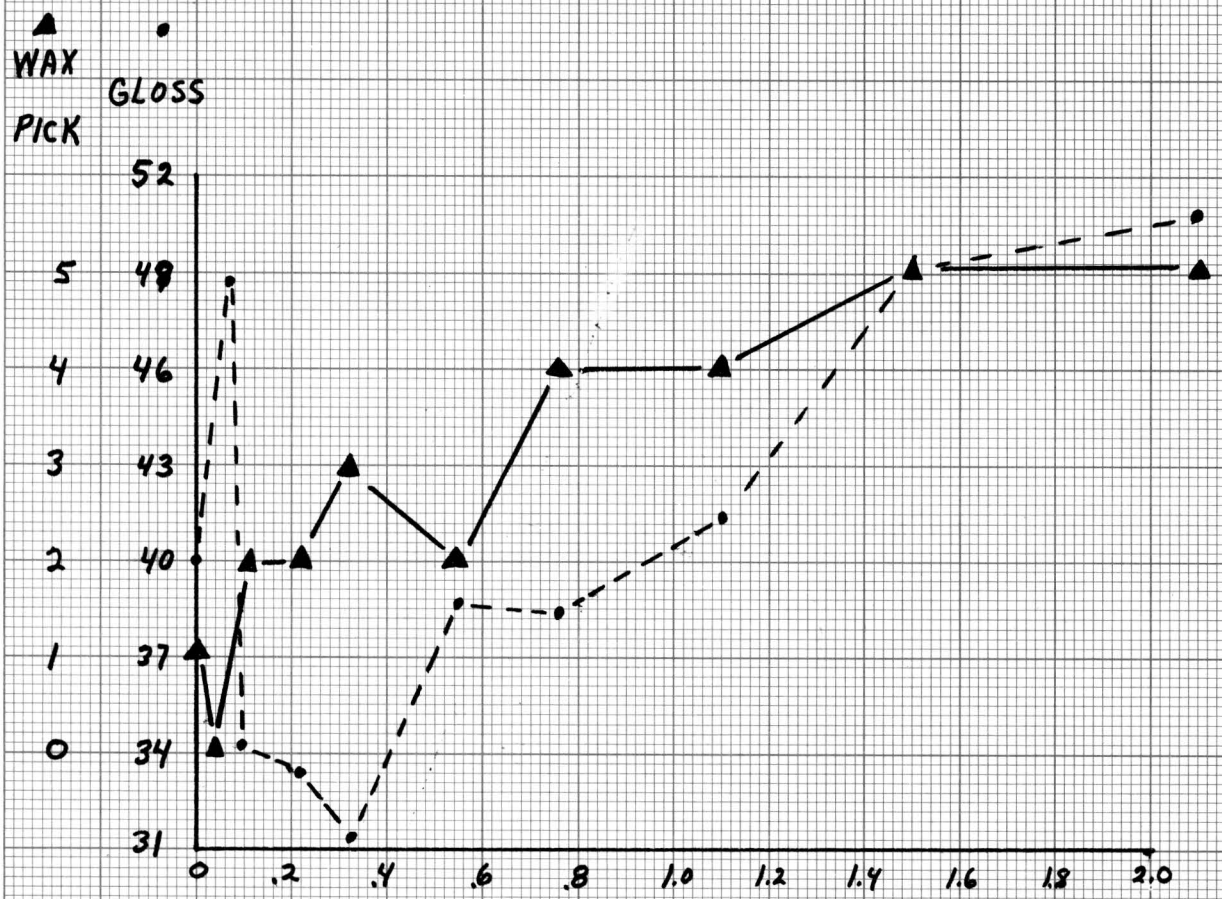


FIGURE-4A

GLOSS, WAX PICK VS. % NaOH



Conclusions:

It was reconfirmed that RSV does a good job on clay-water systems but is completely unusable at adhesive levels greater the 5 pph. Because it was impossible to determine RSV with the centrifuge method of coating color above 5 pph, it was assumed that by adding a constant amount of starch to samples of clay of predetermined RSV, the relative RSV would remain constant. Smoothness, opacity, gloss, and brightness were plotted against the theoretical RSVs of the respective systems. No correlation was found between RSV and sheet properties but an increase in the % electrolyte added did indicate an increase in the gloss of a system which could not be explained above pH of seven. Below a pH of seven tests indicated that acid hydrolysis of the starch was occuring in the system.

Literature Citations:

1. Robinson, J. V., "The dispersion of pigments for coating color; Concept and Theory". Tappi 42, No. 6: 432-438 (June, 1959).

2. Moore, J. L., "The Effect of Starch on Clay Dispersions". Unpublished Bachelors Thesis, Western Michigan University, April 1966.

3. Kline, J. E., "The Application of Verwey-Overbeek Theory to the Relative Sediment Volume of Kaolin-Water Dispersions". Unpublished Masters thesis, Western Michigan University, August 1966.