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The Effect of Clay Particle Size on the Optical Properties of Filled Handsheets

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THE EFFECT OF CLAY PARTICLE SIZE ON
THE OPTICAL PROPERTIES OF FILLED HANDSHEETS

by

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ABSTRACT

In this experiment two coating clays and two filler clays were used as fillers to find the effect of particle size on optical properties on filled handsheets.

Klondyke and Nokarb were used as a filler clays to improve the optical properties. Coating clays, H. T. predispersed and Ultra-white-90 were less effective than filler clays. Scattering co-efficient can be improved with coating clays. The reason may be the smaller the particle size better scattering co-efficient. This experiment suggests alum is not necessary in order to improve the opacity and brightness of filler clays. Retention of Klondyke and Nokarb increased without alum, suggesting that alum must be used at a proper pH in order to get the improvement in properties.

TABLE OF CONTENTS

THEORY AND BACKGROUND

Clay used in a general sense refers to a group of naturally occurring minerals composed of hydrogen aluminum silicate consisting of very fine grained crystal fragments and showing plastic properties (1). Kalonite, used extensively in the paper industry in clay coatings and as fillers, is a hydrated aluminum silicate mineral of definite chemical composition (2).

The Kalonite crystal is composed of silicon, aluminum, hydrogen and oxygen in the ratio of 2.2 - 4.9 respectively. The crystal is built up of alternating layers of silica and alumina. Hydroxyl and oxygen valency linkages, bonds the layers of silicon and alumina together (1).

Coarse clays are generally used as filler pigments and the finer clays as coating pigments. This is because primarily the finer particles are made up of platelts which orient themselves on the paper surface resulting in high gloss development (3).

Mi (4) developed a fundamental relationship between the size of spherical particles and hiding power for different wave lengths of incident-radiation.

Maximum hiding power could be expected when the diameter of the particle or the particle size was slightly higher than the wave lengths. This theory could not be applied to clay-cellulose system, particle neither non-dispersed or spherical. A practical

relationship was provided by Kukelka and Munk and is graphically represented by Judd (5) in order to find the scattering co-efficient and thereby relating to the optical properties.

The scattering co-efficient of a pigment depends on its particle size, shape and the difference between the index of refraction and that of surrounding medium. The scattering value depends on the method of preparation and use of the pigment. The particles finer than the wave length of light, scattering increases as the particle size increases, whereas for particles coarser than the wave length of light, reflection decreases as the particle size increases. The degree of aggregation of the pigment particle is also important because any tendency of the individual particles to coalsce into large aggregates will bring about a corresponding reduction in the number of pigments surfaces available for refraction (7).

Filler greatly increases the opacity and brightness of the average paper. The opacity and brightness of paper are determined by the amount of light scattered, reflected and absorbed by the paper. Fillers increase the brightness and opacity because they function mainly by increasing the reflection and refraction of light. Colored pigments have a greater opacifying power than white pigments because of their great light obsorption power, but of course they do not produce a very white paper (8). The opacity of paper depends upon the thickness of the paper, the

number of individual particles making up the sheet and refractive indices of these particles. In general opacity and brightness of unfilled paper depends on the difference in the index of refraction between air and cellulose that is between 1 and 1.53. Clay, which has a fractive index close to that of cellulose, increase the opacity by increasing the area of light scattering. The opacity increases as the particle size of the pigment is decreased, because smaller particles have more surface area through which the light passed and be refracted and reflected. The increase in brightness depends partly on particle size (9) and covering power of the pigment. If the pigment is brighter than the pulp a decrease in particle size will increase the brightness.

The retention of fillers by the paper making system and an understanding of the opacifiction of paper making systems are necessary to study retention. Opacification is intimately connected with particle and agglomorate size, sheet structure, filler packing, and particle environment. The retention processes have been defined by Steele (10), to be sieving, co-flocculation and mechanical attachment. Co-flocculation is of predominent importance in the retention of the paper making fibers of high opacity pigment.

Pulp used: R. bleached softwood kraft

Freeness: 450 C.S.F.

Beating time: 1 - 1.50 hours

Method used to find the scattering co-efficient of filled hand sheets:

$$Sp = Spulp\ (C) + S_{Filler}\ (C)$$

C = Concentration

S = Scattering Co-efficient

Pre-mat formation, retention and percentage of retention of free pigment retention properties having different hydro-dynamic properties but common collodial properties are correctable.

Alum is used to obtain the proper amount of flocculation and retention of fillers. This is explained by the colloidal and chemical factors affecting the behavior of alum. Alum at a proper pH will hydrolyze to form positively charged alumina which acts as an electrostatic component binding the negatively charged fillers to the negatively charged fibers.

There are a few relatively colloidal materials which have an electropositive surface but the colloidal alumina resulting from the hydrolysis of alum is strongly electropositive in nature. As the pH is increased the positive character of the solution is

diminished and the slightest excess of alkali, normal electro-negative aluminum hydroxide is formed. The positively charged alum under favorable conditions appear to be important factor in retention. In practice, it is known that the retention increases with increased sheet weight and other properties. With most pigments, there appears to be a range where percentage retention is at a maximum. Retention has been explained as being due to (a) filtration of the pigment particles at the interstices between the fibers (b) adsorption (12) of the pigment on the surface and many more. Highest pigment retention was obtained with pigments of large particle size.

The mechanism of retention is still obscure but appears to rely on a combination of mechanical, chemical and physical properties brought about by beating.

Fillers have been used as a loading material due to its fine qualities. Filler improves the printing properties of paper by increasing opacity, decreasing its size through better formation of the sheet.

EXPERIMENTAL DESIGN

A commonly used filler clay would be a good raw material to be used for filling handsheets. In this experiment the following clays were used:

1. Ultra-white - 90
2. H. T. predispersed
3. Klondyke
4. Nokarb

PREPARATION OF HANDSHEETS FOR FILLER EVALUATION

To minimize variations in handsheet properties it is necessary to follow or use the following procedure.

For a series of mineral comparisons prepare one master batch of clay fiber mixture, refined in the Valley Beater to a degree that will give moderately good formation in handsheets. For four clays 5 ± 1 handsheets of 2.2 ± 0.2 gms per 8" x 8" at each levels of filler one would need approximately about 600 gms or one Valley Beater.

PAPER AND FILLER EVALUATION

1. Weigh each handsheet in the constant humidity room to nearest gm on the swing balance. It is necessary to adjust ob-

served opacity to basis of common sheet weight 2.2 gms.

2. Measure opacity and brightness of individual sheets. For brightness, back-up each sheet with the other 4 of the same filler content.

3. To determine the filler level content, substract the percent of ash in the control from that for each of the filled sheets. Divide the resultant difference in percent ash to convert filler ash to equivalent percent over dry filler clay.

4. Scattering co-efficient value determination was made by using "Kubelka-Munk" procedure.

5. Graphs are drawn by taking the percent ash as the basis, to show effect on opacity, brightness and scattering co-efficient.

Adjust the consistency of fiber in the proportioner tank of the Noble and Wood Sheet Mold equipment and the size of fiber sample used to form a sheet to make 25 to 30 sheets of 2.2 $\pm$ 2 gms from one tank. Be certain that stock in the tank is always effectively agitated. It is convenient and advisable to prepare the filler clay for addition as a dispersion. Different percent of clay fractions were prepared to make handsheets. The clay should be added to the fiber in the proportioner tank. For each clay fraction make 2 or 3 control handsheets before the addition of clay.

The first batch of handsheets were made with the addition of 5% alum as a solution to the beater. In order to get good retention, the percentage of clays was increased. The second set of handsheets were made with the same clay percentages but without alum.

PRESENTATION AND DISCUSSION OF RESULTS

EFFECT OF PARTICLE SIZE ON OPACITY AND BRIGHTNESS

Brightness and opacity did not improve when handsheets were made with alum compared to the improvement in these properties without alum.

Opacity and brightness did increase as the percentage of ash was on the increasing side without alum. Ultra-white and H.T. predispersed clays did increase the opacity and brightness as the percentage of ash was increased. At the same percentage of ash content, Klondyke and Nokarb had more improvement in opacity and brightness. Alum was used to retain the clays in order to get improvement in opacity and brightness. This shows that the larger the particle size the better opacity and brightness. Klondyke and Nokarb covers more surface area in the handsheets because they were retained better.

The results show that Ultra-white and H.T. predispersed function as well as fillers to a certain percentage of ash content. After that any more addition of these clays does not improve the optical properties.

TABLE I

5 % ALUM

Type of Clay	% Ash	Opa-city	Bright-ness
Ultra-white 0.5	.023	63.5	57
	.032	64.4	59.4
	.054	66	63

Type of Clay	% Ash	Opa-city	Bright-ness
H.T. Predis-persed 0.8	.0155	67	53
	.024	69	56
	.053	71	59

Type of Clay	% Ash	Opa-City	Bright-ness
Klondyke	.023	67	56
1.4	.032	69	57
	.054	69	59

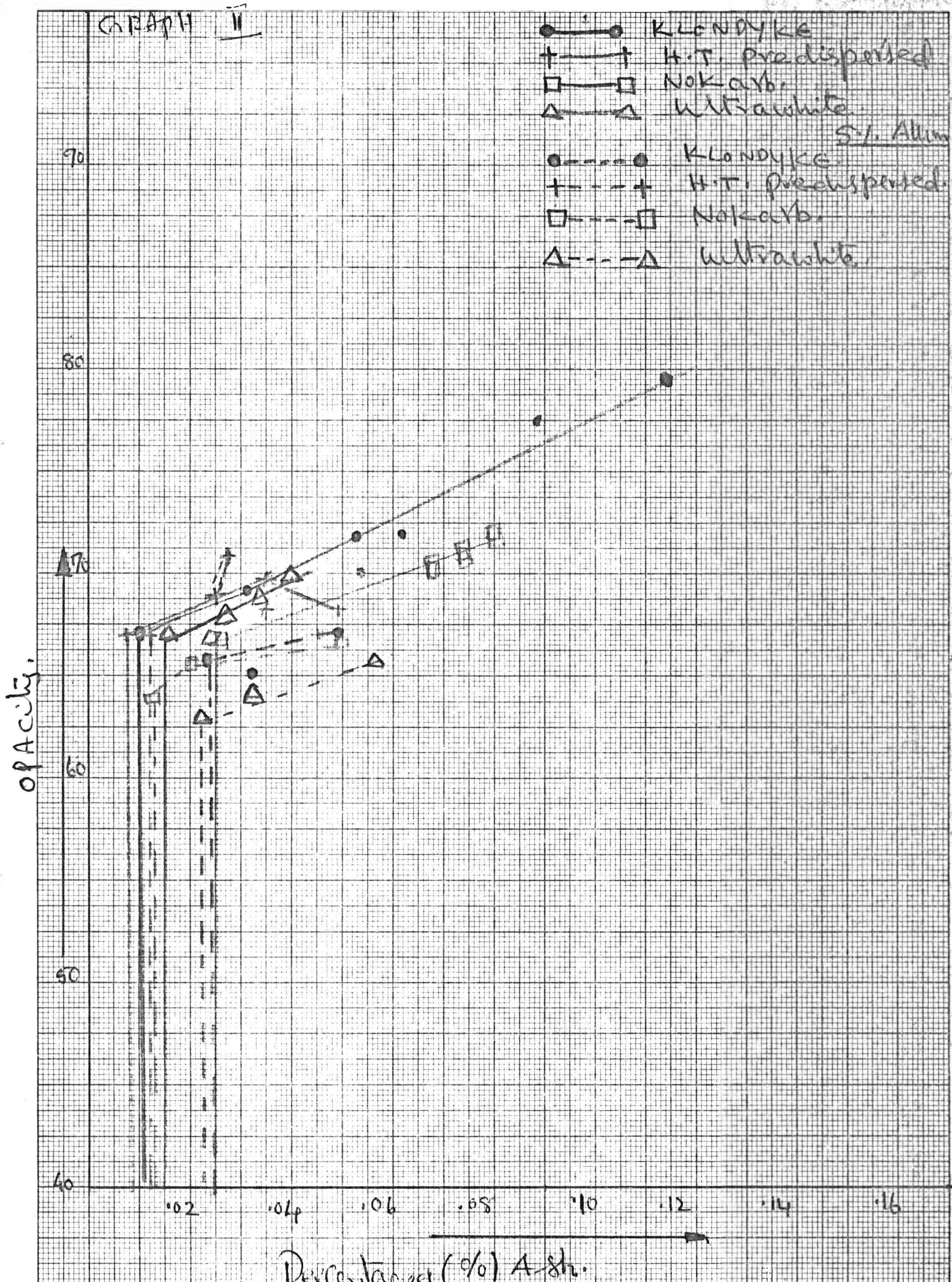
Type of Clay	% Ash	Opa-city	Bright-ness
Nokarb	.014	65	59
4.9	.021	67	60
	.036	67	60

TABLE II

NO ALUM

Type of Clay	% Ash	Opa-city	Bright-ness	Type of Clay	% Ash	Opa-city	Bright-ness
Ultrawhite	.0155	67	57	H.T. Predis-persed	.0135	67	56
	.034	69	59		.032	69	56
	.039	64	62		.027	68	60
	.022	61	63		.034	66	65
	.027	66.9	63.6		.044	67	63
	.032	67	64		.052	68	62

Type of Clay	% Ash	Opa-city	Bright-ness	Type of Clay	% Ash	Opa-city	Bright-ness
Klondyke	.015	66	59	Nokarb	.014	64	55
	.034	65	61		.023	66	57
	.039	67	61		.048	67	59
	.061	72	62		.063	70	59
	.089	75	64		.067	71	62
	.115	77	65		.081	72	64



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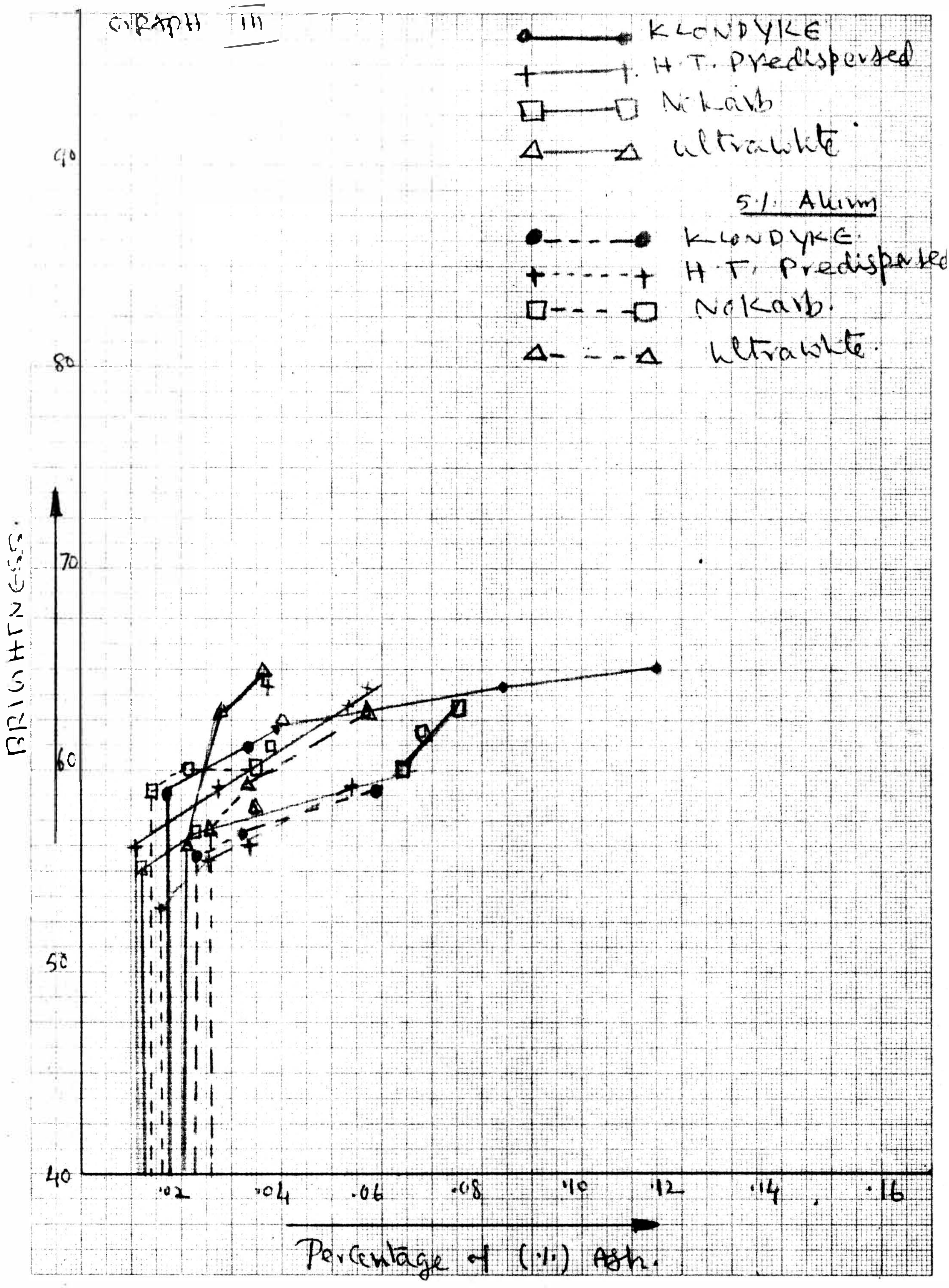

GRAPH III
KLONDYKE
H.T. Predispersed
Nikarb
Ultrawhite
5% Alum
KLONDYKE
H.T. Predispersed
Nikarb.
Ultrawhite.
BRIGHTNESS
90
80
70
60
50
40
·02
·04
·06
·08
·10
·12
·14
·16
Percentage of (·1·) Ash.

EFFECT OF PARTICLE SIZE ON SCATTERING CO-EFFICIENT

Handsheets were made according to the procedure first with alum and secondly without alum using different clays of different particle size.

It can be seen in graph (1) that scattering co-efficient did not improve with alum. On the contrary scattering co-efficient did improve without the addition of alum.

In the case of Nokarb and Klondyke, scattering co-efficient did increase to a maximum and dropped off as the percent ash was increased further. Whereas in the case of Ultra-white and H.T. predispersed the scattering co-efficient increased as the percent ash was increased. In general for all four clays, scattering co-efficient was increased as the percent ash was increased.

With Klondyke, the scattering co-efficient increased to a maximum then dropped off as the percent ash was increased. But in the case of Nokarb the scattering co-efficient leveled off as the percent ash was increased.

From this it can be said that the smaller particle size improves scattering co-efficient. As the particle size increases the scattering co-efficient decreases.

TABLE III

% Filler Added	Fillers Retained with 5% Alum: Ultra-white	H.T.	Klondyke	Nokarb	Fillers Retained without Alum: Ultra-white	H.T.	Klondyke	Nokarb
10	.023	.013	.024	.014	.015	.013	.015	.014
20	.032	.024	.032	.023	.034	.032	.034	.023
30	.054	.053	.054	.048	.039 .022	.027 .034	.039 .061	.048 .063
40	---	---	---	---	.027	.044	.089	.067
50	---	---	---	---	.032	.052	.115	.089

EFFECT OF ALUM ON RETENTION

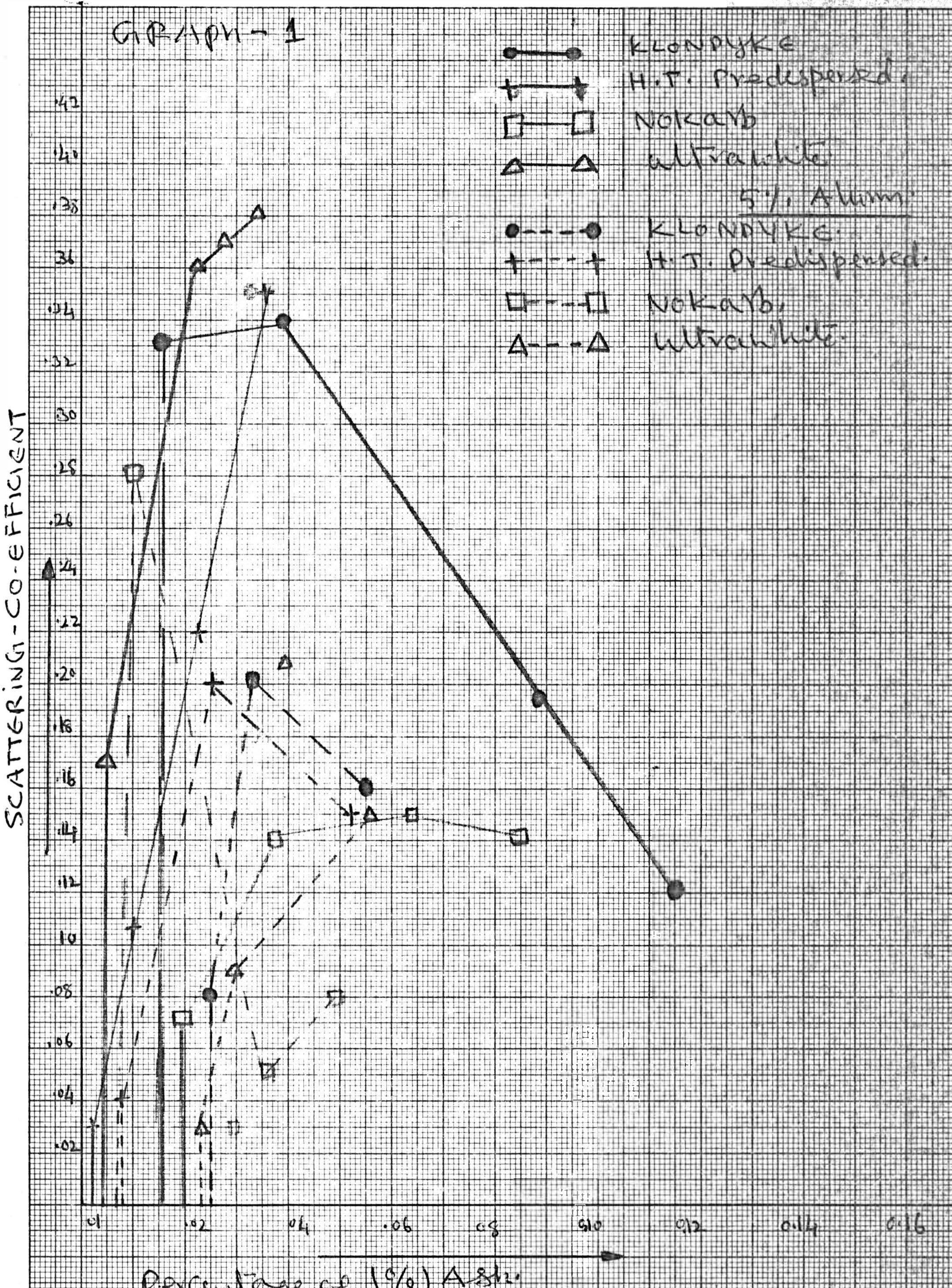
Handsheets made with 5 percent alum had a pH 8. The second set of handsheets made with the same clays but without alum had a pH of 7.5. The addition of fillers was increased in order to find the effect of retention.

Filler clays retained better without alum. Klondyke and Nokarb retained better when compared to the coating clays. As the amount of filler added was increased the retention was increasing for filler clays without alum. This may be due to the fact that filler clays have a bigger particle size when compared to the coating clays.

The pH used in these studies may be high for retaining the fillers. At a higher pH the clay is dispersed. Instead of flocculation, we get dispersion. This may be the reason for not retaining the fillers at a higher pH. This suggests that proper pH is necessary to retain the fillers on the sheet. As the particle size is big it might retain and better retention was obtained. The retention was up with Klondyke and Nokarb which have a larger particle size than Ultra-white and H.T. predispersed.

TABLE IV

Types of Clay Used	Average Particle Size	Scattering Co-efficient (Max.) No Alum	5% Alum
Ultra-white-90	0.5	0.38	0.15
H.T. Predispersed	0.8	.34	0.17
Klondyke	1.4	.35	.20
Nokarb	4.9	.15	.09


GRAPH - 1
KLONDYKE
H.T. Predespersed.
NOKARB
ultrawhite
5% Alum
KLONDYKE.
H.T. Predispersed.
NOKARB.
ultrawhite.
SCATTERING - CO-EFFICIENT
Percentage of (%) Ash.
.42
.40
.38
.36
.34
.32
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
.01
.02
.04
.06
.08
0.10
0.12
0.14
0.16

CONCLUSIONS

This project was carried out in order to find the effect of particle size of clays on filled handsheets with respect to optical properties.

1. Ultra-white and H. T. predispersed clays can be added to improve opacity and brightness. After maximum is reached, any more addition of these two clays does not improve the optical properties.

2. Klondyke and Nokarb can be used to improve the optical properties. As the percent ash was increased the optical properties went on increasing.

3. Scattering co-efficient increased with increased filler in the case of Ultra-white and H. T. predispersed. On the contrary Klondyke and Nokarb did not have the same effect, as the percent ash was increased, scattering co-efficient after reaching a maximum decreased. The smaller the particle size the better scattering co-efficient.

The above results were obtained without the addition of alum.

The flocculating effect of alum might either increase or decrease the retention and effect the optical properties. The reason may be that the quantity of addition of alum might not have been sufficient to have a predictable effect.

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