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The Influence of Base Sheet Moisture on Size Press Pick-Up

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by

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ABSTRACT

An investigation was conducted to determine the relationship, if any, between base moisture before the size press and actual size pick-up. While size press operation is subject to the effects of many variables, existing literature indicated that maximum pick-up would be realized at twenty percent moisture, while the acceptable on-machine moisture range is five to twelve percent before the size press.

A machine trial was conducted on the pilot fourdrinier at Western Michigan University, wherein the coat weight was monitored as a function of pre-size press moisture. This study revealed that higher coat weights would be realized at increased adhesive level, increased total solids, and increasing machine speed. However, there was no discernable effect on coat weight due to changing moisture content. Further investigation is indicated.

TABLE OF CONTENTS

TABLES & FIGURES

INTRODUCTION

Throughout the development, and consequent wide spread use of the size press in paper manufacture much information has been gathered regarding the effects of size press operating variables. Despite indications to the contrary, there still seems to be a general lack of understanding in actual size press operation. The exact role of many variables (both machine and sheet variables) is unknown or, at least, disputed. The variable of interest in this study is base sheet moisture before the size press.

It was hoped that through the completion of this project, useful data would be collected regarding the role of sheet moisture on pick-up of a pigmented size. Because the effectiveness of surface treatment is reflected in the final products' quality, it is important to achieve a means of effectively and efficiently controlling size press pick-up.

THEORETICAL DISCUSSION

The surface treatment of paper is not new to the paper industry. Among the several methods used in surface treatment, the size press finds many applications in the manufacture of paper. It has been used for many years, and in many different forms to apply both adhesive and pigment to the sheet.

There are many reasons for applying size to the sheet surface; one important factor is the marked improvement in sheet quality. The treated surface will, in general, be smoother and more uniform than the untreated sheet. This results in a better surface for subsequent coating or printing

processes (1). Another factor which promotes the application of pigmented size at the size press is that pigments can serve to offset the brightness loss that occurs due to starch application to the sheet. These same pigments also serve to increase the ash content of the sheet (2). Furthermore, through the utilization of a pigmented size in surface treatment, a heavier sheet can be produced at lower cost, since pigments generally cost less than fiber (1). Hence, the importance of achieving controlled pick-up at the size press.

There are many variables in size press operation, each affecting pick-up. They can be grouped into three major categories as follows: machine design variables (roll geometry, diameter, and material), machine operating variables (speed, nip pressure, pond depth), and size and sheet variables (solids, viscosity, temperature, internal sizing, surface smoothness, density, moisture content) (3).

Machine variables have been found to have a marked effect on size press operation. Higher coat weights are usually achieved through the use of a horizontal size press; this phenomenon is attributed to the pool that forms in the nip of the press during operation (4). Roll diameter and material directly affect pick-up: as the width of the nip increases, the size pick-up also increases (5). Operating variables also influence size pick-up. One method used to increase pick-up is differential relative surface speed between the two press rolls. By overspeeding one roll, size can be drawn through the nip and held by the sheet (5). The machine speed (and hence, dwell time in

the nip) was found to have an inconsistent effect on pick-up, although it is generally believed that reduced size uptake results at reduced machine speeds (6). Nip pressure is important only in that it must remain constant all along the nip, since uniformity across the web is imperative (4).

Base sheet uniformity is also important in achieving best results at the size press. Henadi, et al., have concluded that "moisture uptake in the size press is a function of the paper's moisture content before surface sizing" (7). to realize uniform surface treatment across the web, sheet moisture must be carefully controlled. The effects of sheet moisture are overshadowed, however, by the effects of internal sizing. The degree of internal sizing has the greatest effect of all sheet variables on pick-up: the more heavily sized sheet will absorb less than a soft sized sheet during surface treatment (3), (6). Size pick-up is also influenced by sheet density, since a porous sheet will absorb more size (5).

Regarding the size itself, there are many factors to be considered. Solids should be run as high as possible to maximize coat weight (pick-up is directly proportional to solids content) (3). However, excessive solids may result in extremely high viscosities that interfere with application operations. Maximum pick-up is achieved at highest possible viscosity and optimum size temperature is believed to be approximately 120°F. Temperatures higher than this reduce penetration and, consequently, pick-up (3), (6).

Few studies have been conducted to determine the influence

of base sheet moisture on size pick-up. Chilson and Fahey of Forest Products Laboratory investigated the effect of certain variables, such as moisture level, on starch absorption. They found that at higher moisture levels, greater starch pick-up is realized. Maximum pick-up was achieved at approximately twenty percent moisture (8). Results similar to these were obtained by Eklund in his study of starch penetration (9). He ascertained that optimum moisture content for maximum starch penetration is in the range from three to six percent moisture. He also theorized that the water already in the sheet "acts as a sponge and provides a medium for the starch to travel into the sheet, but at higher moistures the sponge effect is decreased and the excess moisture acts as a saturation," thus reducing pick-up (9).

Eklund's conclusions are confirmed by the capillary theory with respect to liquid absorption of a fibrous network. The liquid absorption of a capillary is a function of its pore radius and height of liquid ascent in the capillary (10). The average pore radius is comparatively small at low moisture levels and increases as a function of moisture level in the network (see Figure 1) (11). It has also been observed that as pore radius increases, the height of liquid ascent approaches zero (see Figure 2) (10). Thus, it must be concluded that a limited amount of moisture in a fibrous system such as paper will promote capillary absorption; however, too much moisture can be detrimental.

EXPERIMENTAL PROCEDURE

Based on the information previously cited, it was determined that the most effective method available for experimental work was the actual manufacture of paper on the pilot fourdrinier at Western Michigan University, as opposed to using laboratory scale equipment. The objective of such experimentation was to vary the base sheet moisture before the size press (by any means available, ie. steam pressure, manipulation of nip pressure in the press section), determine the actual sheet moisture, and monitor size press pick-up as a function of changing base sheet moisture.

Materials

The furnish of the base stock was as follows: 50/50 hardwood-softwood kraft, with 0.5% rosin and 0.75% alum internal size. The stock was refined to 350 CSF (Canadian Standard Freeness). A fifty pound/3300 ft^2 base sheet was used.

Two solids levels were selected for size application to the sheet. These were fifteen percent total solids, and thirty percent total solids. Each of these solids levels was further classified by pigment to adhesive ratio. The levels selected were one part pigment to one part adhesive and one part pigment to two parts adhesive. The pigment selected was #2 coating clay and the adhesive a thermally converted starch. Size temperature upon application to the sheet was held constant at 120^{o}F. The pilot fourdrinier has a vertical size press.

Procedure

At the lower machine speed investigated (fifty feet per

minute) the proper basis weight was achieved. The dryer steam was controlled to yield the desired moisture level, and a sample of the base sheet was taken for gravimetric determination of moisture content. The reel was flagged at the appropriate sample locations so that size coated samples could be taken.

This procedure was repeated at a higher machine speed (seventy-five feet per minute). These machine speeds were selected because of the limited dryer capacity.

The base sheet samples were stored in plastic bags to prevent moisture changes. The samples were weighed, oven dried, and reweighed to determine the moisture content. The sheet samples were weighed; the coated sample weights were, of course, compared to the uncoated sheet weight to determine the actual size pick-up.

RESULTS

A linear regression analysis was performed on the data (see Table I) to determine the relationship between moisture and size press pick-up. These relationships at different solids and pigment/adhesive ratios are summarized as follows:

$y = m x + b$ where y = coat weight at a given moisture

m = unit change in coat weight per unit change in moisture

b = coat weight at 'zero' moisture

x = moisture

Size Composition: Total Solids (%)	Size Composition: Pigment to Adhesive	Machine Speed (fpm)	Regression Equation	Avg. Coat Wt. #/3300ft^2
15	1:1	50	y=0.006x+2.92	3.0
15	1:2	50	y=0.08x +3.4	2.7
15	1:1	75	y=0.05x +3.9	3.4
15	1:2	75	y=0.024x+2.3	2.6
30	1:1	50	y=0.155x+1.1	2.4
30	1:2	50	y=0.21x +1.6	3.3
30	1:1	75	y=0.1x +2.4	3.4
30	1:2	75	y=0.02x +3.6	3.8

DISCUSSION OF RESULTS

These data indicate a trend of increasing size pick-up at a lower pigment to adhesive ratio (ie., more parts adhesive to one part pigment). This effect is independent of machine speed and total solids content, and can be explained in terms of sheet absorption. The elevated pressure in the nip forces the sheet to absorb. The increased absorption and consequent retention account for the observed increases in coat weight.

It can also be noted that a higher average coat weight was achieved at increased machine speeds. Although absorption will decrease as dwell time in the press nip decreases (ie., with increasing machine speed), higher coat weights will be realized at increased machine speeds. The fluid that enters the press nip creates a hydraulic wedge pressure that actually helps to force the rolls apart, thus allowing more size to be carried by the sheet. This hydraulic wedge pressure increases

with increased machine speeds and will ultimately result in an increase in pick-up at high speeds.

The coat weight also increases as total solids increases. The fact that increased solids content will produce increasing coat weights is well accepted in the paper industry. However, due to problems in runability (high viscosities, patterning and misting, for example) the solids level used in size press application is limited. The amount of increase in this case (approximately 0.3#/3300ft^2) is insignificant for a twofold change in solids content. Generally, it is not necessary to achieve extremely high coat weights via size press application since this coating usually serves as a base for subsequent treatment.

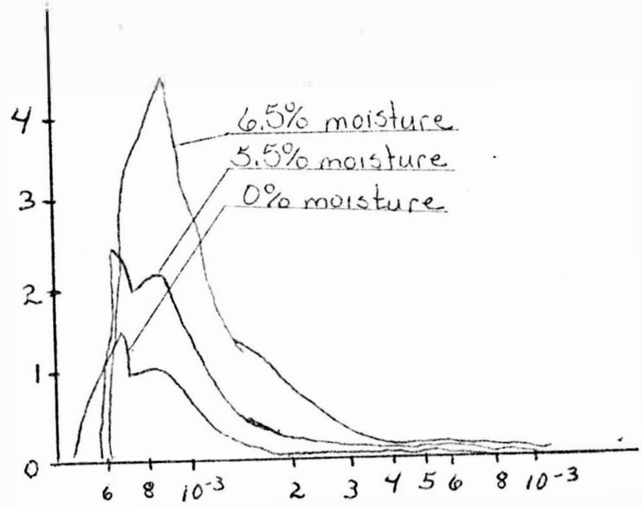
Finally, these data indicate that the effect of varying sheet moisture is negligible with regard to size press pick-up. Each of the equations which defines the relationship between pre-size press moisture and resultant coat weight has a slope of almost zero. In the one case where the line has a non-zero slope it would be necessary to increase the sheet moisture by roughly thirty percent over a typical moisture of five percent to thirty-five percent moisture to increase pick-up by one pound/3300ft^2. No significant change in coat weight was realized for any type coating (pigment/adhesive ratio and total solids) at any machine speed. It has been previously reported that base sheet moisture does indeed influence pick-up, however, this data does not reinforce this theory. Instead, one may conclude that coat weight is constant with respect to base sheet moisture.

CONCLUSIONS

In conclusion, the operation of the size press is subject to the various effects of many separate factors. The size pick-up can be increased by increasing adhesive content on percent total solids, actual total solids and machine speed. Actual size pick-up is independent of base sheet moisture before the size press within the conditions studied. If the manipulation of size pick-up is desired, the machine operator is advised to investigate methods other than changing base sheet moisture.

RECOMMENDATIONS

The results of this study do not reinforce theories that have been proposed by other investigators. If further information on this topic is desired, additional experimentation, perhaps at an actual manufacturing site, is indicated. However, investigation of variables such as adhesive level, percent solids and machine speed may reveal more pertinent information. These appear to be the significant factors related to size press pick-up.

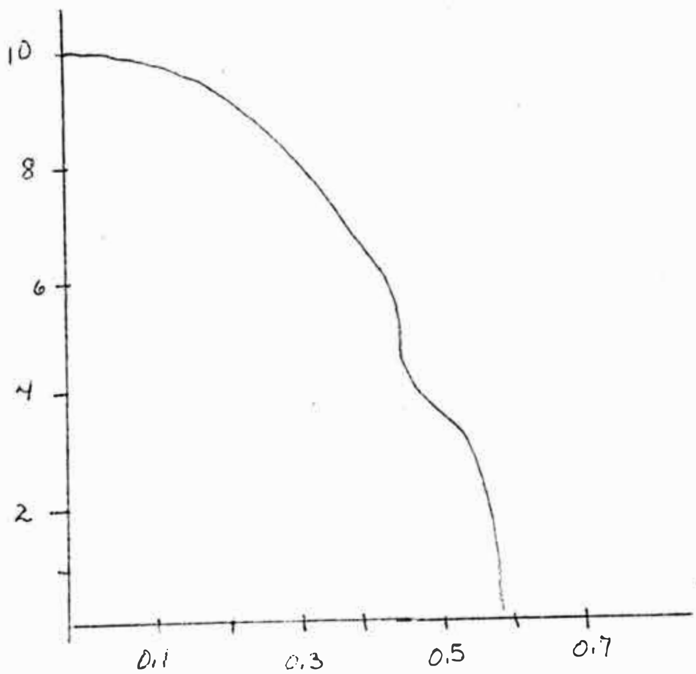


Pore Area (mm^2)

Figure 1

Pore Radius (cm)

Pore size distribution of paper with different moisture content



Height (cm)

Figure 2

Liquid Volume/Total Volume

Liquid volume ratio vs. height of liquid ascent in a porous system

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APPENDIX

Figure 3. Coat Weight vs. Moisture for 30% Total Solids at 50 fpm

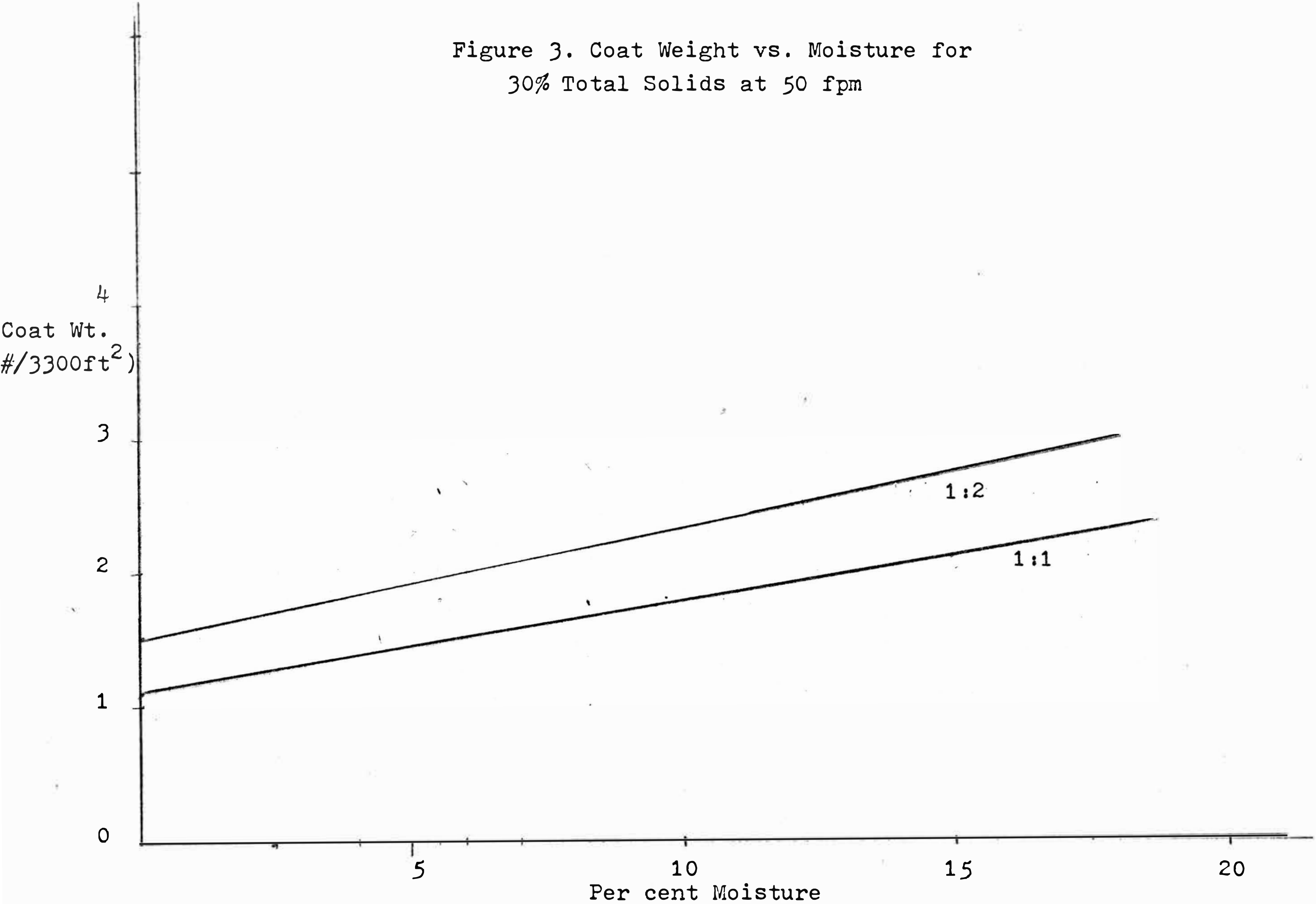

Figure 4. Coat Weight vs. Moisture for
30% Total Solids at 75 fpm

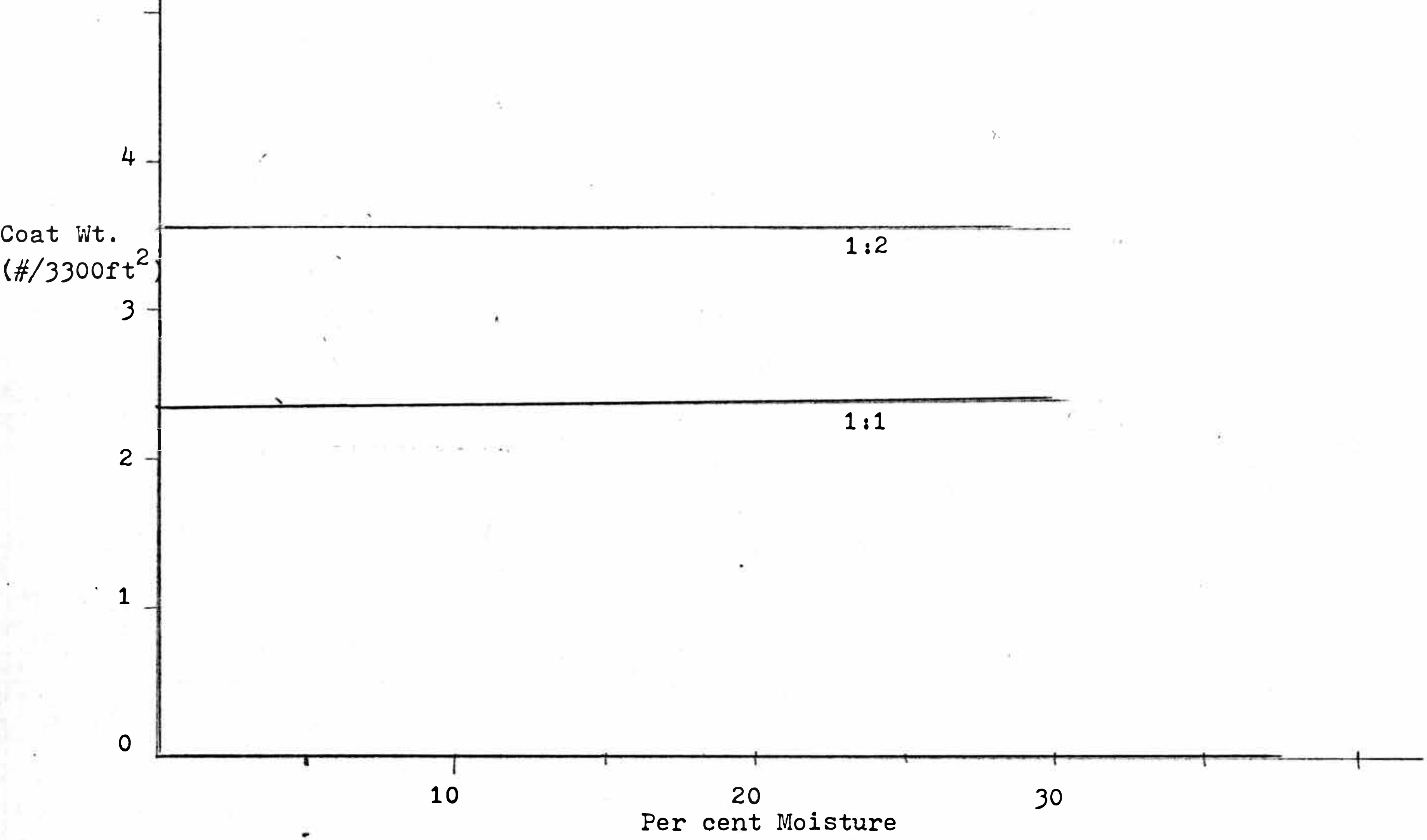

Figure 5. Coat Weight vs. Moisture for
15% Total Solids at 75 fpm

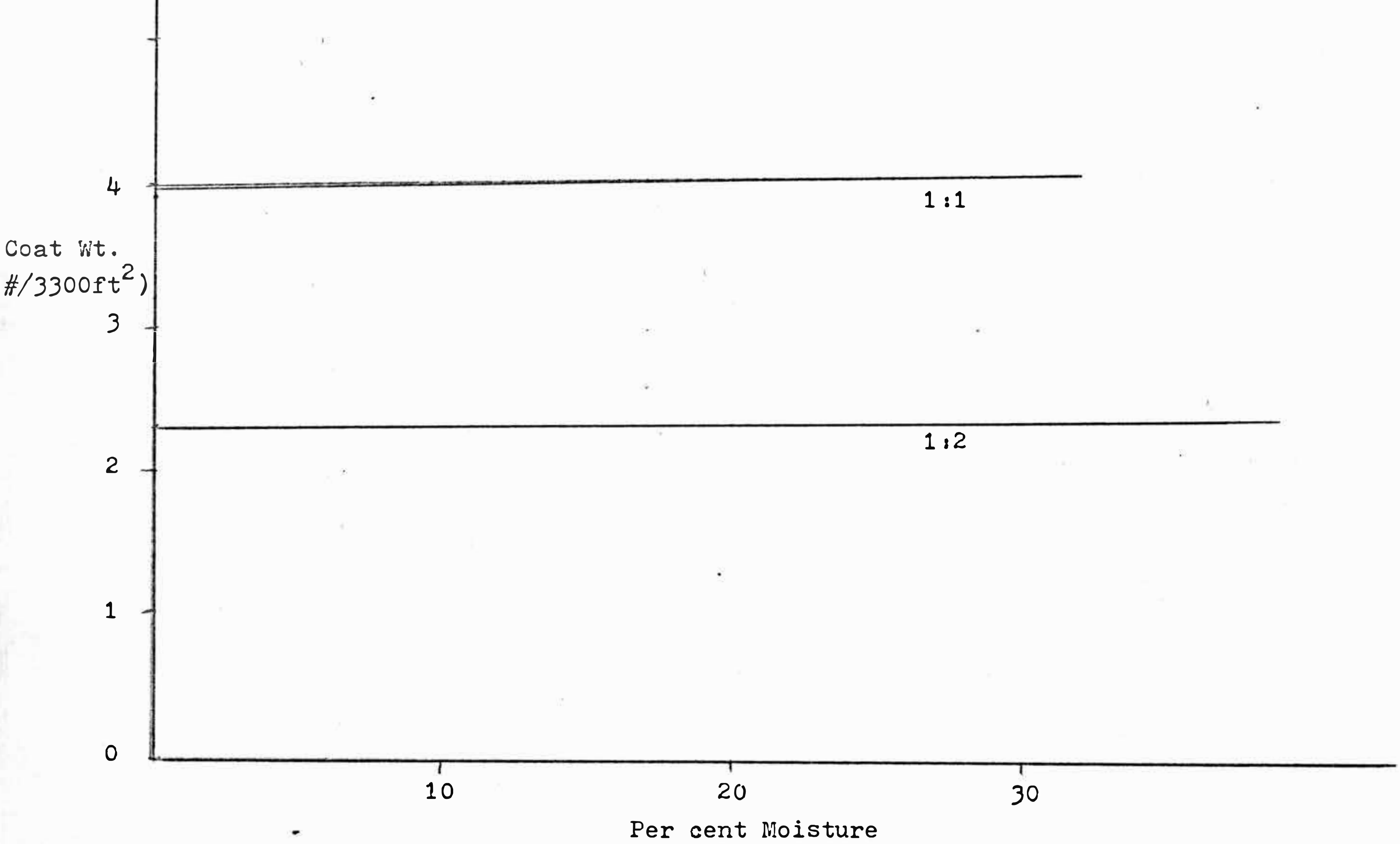

Figure 6. Coat Weight vs. Moisture for 15% Total Solids at 50 fpm

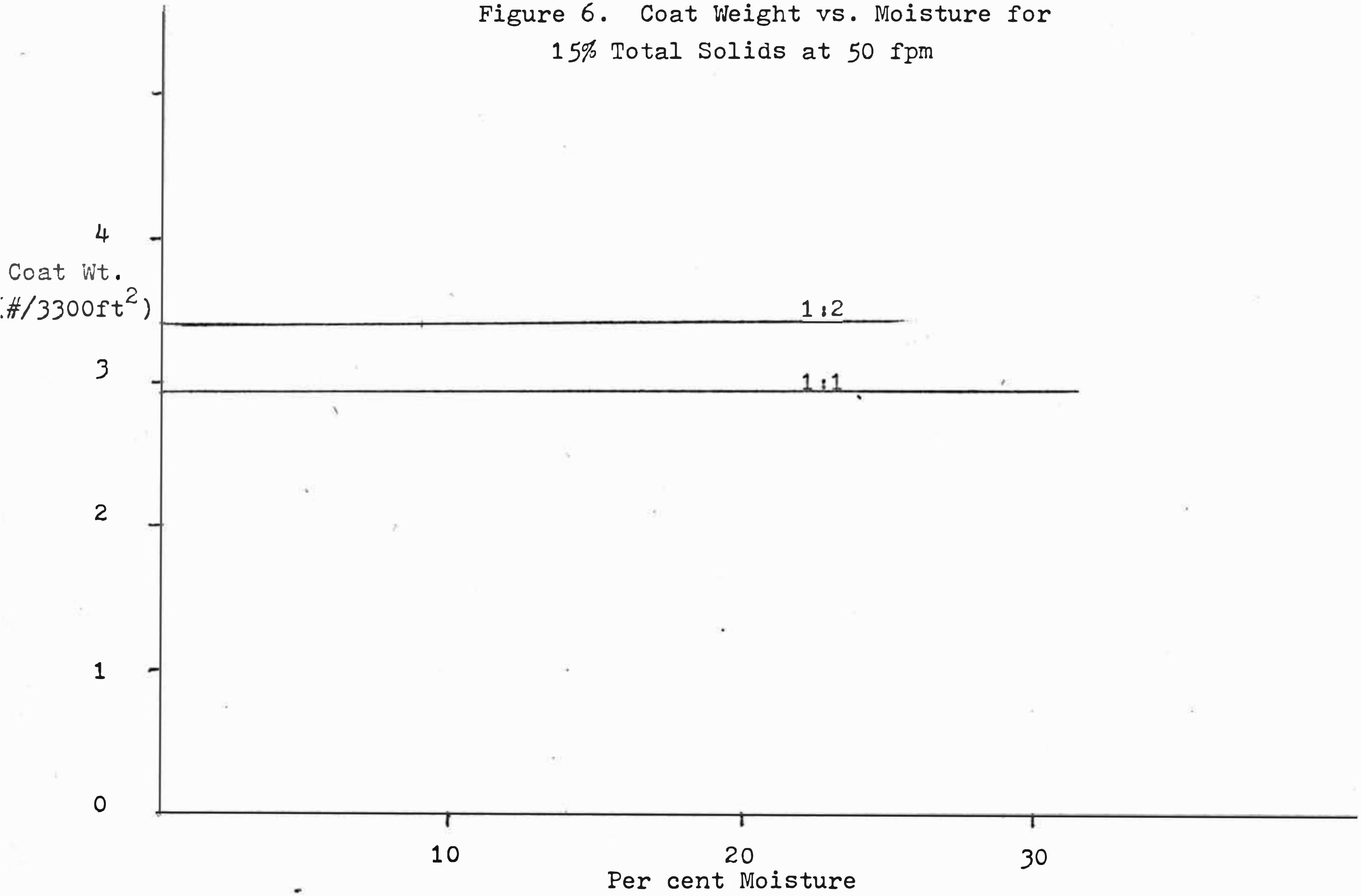

TABLE I

Average Coat Weight Achieved at 50 fpm

15% Total Solids

1:1 pigment/adhesive ratio

Avg. Coat Weight(#/3300 ft^2)	% Moisture
3.02	29.0
2.93	24.1
3.41	8.8
2.83	6.2
3.60	10.0
2.24	5.2

15% Total Solids

1:2 pigment/adhesive ratio

Avg. Coat Weight(#/3300 ft^2)	% Moisture
3.58	5.5
2.78	5.9
3.09	5.6
1.98	7.9
2.52	14.2
2.11	17.2

Average Coat Weight Achieved at 50 fpm (cont'd)

30% Total Solids

1:1 pigment/adhesive ratio

Avg. Coat Weight (#/3300 ft^2)	% Moisture
3.7	17.2
3.17	10.7
1.74	8.6
1.80	5.5
2.60	5.5
1.5	4.5

30% Total Solids

1:2 pigment/adhesive ratio

Avg. Coat Weight (#/3300 ft^2)	% Moisture
2.32	5.0
2.65	5.6
2.73	6.0
2.79	8.3
5.26	10.2
4.21	15.5

Average Coat Weight Achieved at 75 fpm

15% Total Solids

1:1 pigment/adhesive ratio

Avg. Coat Weight (#/3300ft^2)	% Moisture
3.0	28.6
2.57	16.9
1.60	6.6
3.29	5.4
5.09	5.7
4.84	5.0

15% Total Solids

1:2 pigment/adhesive ratio

Avg. Coat Weight (#/3300 ft^2)	% Moisture
3.55	3.8
2.92	6.0
3.21	7.2
3.40	17.4
2.54	36.4

Average Coat Weight Achieved at 75 fpm (cont'd)

30% Total Solids

1:1 pigment/adhesive ratio

Avg. Coat Weight (#/3300 ft^2)	% Moisture
5.36	29.3
2.96	12.8
3.65	7.0
3.36	6.0
2.80	5.6
2.40	4.9

30% Total Solids

1:2 pigment/adhesive ratio

Avg. Coat Weight (#/3300 ft^2)	% Moisture
4.07	4.4
2.90	6.0
3.65	5.3
4.41	11.2
3.62	18.2
4.18	28.7