12-1973

The Effects of Speed of Web on the Coat Weight Variation in Blade Coating

Pak Kee Lee
Western Michigan University

"THE EFFECTS OF SPEED OF WEB ON THE COAT WEIGHT VARIATION IN BLADE COATING"

by

Pak Kee Lee

A thesis submitted to the

Faculty of the Department of Paper Science and Engineering

in partial fulfillment

of the

Degree of Bachelor of Science

Western Michigan University
Kalamazoo, Michigan
December, 1973

ABSTRACT

Nurmerous works have been done on the investigation of coat weight variations by various researchers. The mechanism of the variation, in a given base stock, is explained by the two models - the hydrodynamic pressure which is a strong function of the web speed, and the visco-elastic or normal force. For a given given coating color, viscosity is a function of the web speed which causes the shearing action to take place. Increasing the speed will cause an increase in hydrodynamic pressure as well as visco-elasticity, which tend to lift up the blade and thus a higher coat weight will be obtained. However, speed will alter the time interval available for coating penetration and this acts to reduce the coating weight. The combination of these two effects governs the coat weight variation almost entirely. It is found that at low blade pressure, the increase in coat weight with respect to speed is rapid and great. However, the increase is lowered with higher blade pressure. At extremely high speed and low pressure, the coat weight is found to be decreased somehow. The relationship between the coat weight and the speed of web is so important that it enables one to predict the effect of one on the other.

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INTRODUCTION

It has long been known that the amount of coating applied by a trailing blade coater is related to the base sheet, the coating color and the doctoring action of the blade. The doctoring action of the blade is in turn governed by blade pressure, blade angle and the pressure generated in the coating color by the rotating back up roll and paper in opposition to the blade pressure (most authorities refer this as hydrodynamic pressure but some do include the viscoelasticity of the coating color).

A lot of work has been done in explaining the mechanism of application in terms of the blade pressure and the one counteracting it - hydrodynamic pressure and viscoelasticity, but relatively few have touched on how additives are influencing the rheological properties of the coating color and hence its viscoelasticity. Besides, most works were done on pilot coaters with speed limited up to 1000 fpm which would not be representative to mill coaters with speed up to 3000 fpm. With the availability of a pilot coater having higher speed, the trend of variation in coat weight can be understood more precisely.

THEORETICAL AND BACKGROUND DISCUSSION

In the analysis of coat weight variations in a blade coater, the first step to be considered is the blade pressure. As suggested by Follette and Fowells (1), blade pressure is the basic mechanism by which coating weight is controlled. It is actually worked out and shown that the coat weight applied is inversely proportional to the square root of the blade pressure (1) and is considered valid in practice generally. However, blade pressure is not the controlling factor in actual operation since it is at all time kept constant during the same operation. The prevailing factor, is, by most of the investigators (1-4), the force that tends to lift the blade and hence reduce the doctoring action (opposing to one another) that governs the film thickness which passes beneath the blade. According to Windle and Beazley (4), the force opposing the blade pressure can be considered as a combination of the hydrodynamic pressure which is exerted by a wedge of fluid, and the viscoelasticity of the coating color. As pointed out by Windle and Beazley, certain forces are developed within a material when it is deformed by shearing. Additional forces will be generated normal or perpendicular to the plane when the material is elastic.

These forces are a function of three variables: the shear rate, the viscosity and the shear modulus. Certain liquids, such as solutions of starches, caesin and polyvinyl alcohol do generate normal stresses on shearing and are called viscoelastic.

Both the hydrodynamic pressure and viscoelasticity are viscosity and speed dependent. The relationship between hydrodynamic pressure and speed (and viscosity) can be expressed as (1) :

$$P = u\ s\ G/h^2 \qquad (1)$$

where: P is the hydrodynamic pressure

u is the viscosity

s is the speed of the web

h is the film thickness

G is the geometry-of-system factor

The viscosity, on the other hand, takes the form (4) :

$$E = L\ u^2\ s^2\ b/H\ h\ M \qquad (2)$$

where: L is the length of the wedge

b is the breadth of the wedge

H is the separation of the wedge at the 'wide end'

h is the separation of the wedge at the narrow end

M is the shear modulus of the liquid

E is the total thrust due to normal force

It is clear enough from the two equations that the overwhelming factor is the viscosity of the coating color as well as the speed of the paper and a start at these is most essential. Some authorities consider the role of adhesive and water migration and water retention do play a certain part in the coat weight variation (7,8). Bohmer and Lute (8) showed that the migration of binder and water will change the rheological properties between the first contact pigment suspension, paper and blade.

Rheological properties (solid content, which is by far the most obvious factor that influences the coat weight) of the coating color can be greatly improved by the addition of modifiers (6,8,9,10). Bohmer and Lute showed that both CMC and sodium alginates give substantial increase in water retention values with latices as binder, and thus the coat weight. They argued that such increase is due partly to contact angles between pigment suspensions and paper in the case of sodium alginates and to the viscosity in other additives. The action of such additives, as pointed out by Hern (6), is to allow adjustments in flow characteristics and percent solids, and therefore indirectly governs the

coat weight.

Other factors that will play a part in the coat weight variations (1-4) are the base stock, geometry of the blade and the blade pressure. It is more than an obvious fact that the absorbancy of the paper base has a direct relationship with coat weight which is just the sum of coatings absorbed and staying at the surface of the sheet. Follette and Fowells (1) pointed out that the surface characteristics also are a critical factor in determining the base level of coating. They argued that the predominant force, however, rests on the blade pressure and the hydrodynamic pressure, which either force the coating to penetrate when the blade pressure is great or let the coating penetrate through absorption when it is small.

As shown by the two equations formulated above, both the hydrodynamic pressure and viscoelasticity depend not only on viscosity but on the speed of the web as well. The fact that viscosity of a given coating color is a function of speed makes the latter even more important in the coat weight variation for a given system. Increasing the speed of the machine increases the coat weight applied by increasing the rheological thrust developed. Windle and Beazley (4) has already shown, through the theory of viscoelasticity,

that the coat weight variation is proportion to the square of the speed of the machine and that it is directly proportional to the speed of the web in the hydrodynamic pressure model. Their geometric model indicated that the blade angle and the blade tip angle (the angle between the first linear region of the blade tip and the base) do play a minor part in the coat weight variation.

As suggested in the thesis by Woo (14), a medium sized paper will probably give the best observative results. Blade angle, according to Bliesner (3), should be between 41 and 45 degree and caliper is 0.012 in. The coating formulation was chosed from Woo (14), only that additives like TSPP and Kelgin are not used. This gives a look at the problem at another angle. Solid content is chosed at the highest possible level which is suggested by Hern (6) at around 60%. pH is controlled to the optimum range of 8-9 according to Nadelman (11). Ammonia can be used to increase the pH to this range. The choice of the pigment (#2 HT Clay) and adhesive (SBR) is only arbitrary and maybe due to their popularity.

Speed of running is set at maximum on the coater, preferably at above 1300 fpm to investigate the problem that Woo did not work out. Several speeds are to be attained

for making proper comparison. Blade pressure can be set at different values to confirm the theory and to make the comparison more statistically sound.

Theoretical Approach:

Only one solid level (60%) is to be used according to the formulation in Appendix II. The variation in the coating will be the speed alone, if time permits, the coating will be run at a different blade pressure. Other variables, however, are set constant. Before the formulation is run on the coater, samples could be taken out to determine the Brookfield viscosity as well as the rheogram with the Hercules Hi Shear Viscometer. These might aid to give more about the mechanism due to rheological properties of the coating color.

PROCEDURES

1. Coating Preparation

   a. Dry clay is transferred into the kneader.

   b. The kneader is started and water to the amount shown in the coating formulation to make the wet part of clay, is then added slowly.

   c. Allow the clay to knead for 20 to 30 minutes.

   d. Add the rest of the water and allow several minutes for mixing.

   e. The latex is then added and the mixing is continued for another 5 to 10 minutes.

   f. Drop the batch down to the storage tank. pH of the batch is checked, make the proper adjustment with either ammonia or acetic acid if necessary.

   g. Take another sample out to check for the solid content. Add water if necessary. The batch is then ready for use.

2. Coating Operations

   a. Pump the coating color from the storage tank to the coater with the machine well warmed up in advance.

   b. With the blade pressure set at 1 pli, the raw stock is coated with coating at a speed of 500 fpm. The section of paper is flagged on both the start and end.

c. The speed is then increased to 700 fpm and again the section is flagged.

d. The speed is increased successively to the maximum of 1700 fpm with flags in each of the sections designating a change in speed.

f. At the speed of 1700 fpm, the blade pressure is changed to 3 pli and the speed is decreased successively to 500 fpm. Again flags are inserted in each change in speed.

3. <u>Sampling and Testing</u>

a. The raw stock is obtained for determining the basis weight.

b. From each of the sections, samples are taken out at the beginning of the change, from the middle of the run and from the end of the change.

c. Sheets of paper (of a fixed size) are trimmed out from the samples obtained above.

d. The trimmed samples are donditioned at a constant humidity room and weighed.

e. The samples are then put into crucibles preheated to constant weights; they are then burned to ashes

in an oven for 4 hours with a temperature of 500°C.

f. The crucibles with the ashes are cooled and weighed. Results are tabulated in Appendix IV as coat weight only.

4. <u>Treatment of Results</u>

There will be two sets of data for a given sample. One is obtained through the ash method (Method 1) and the other from subtracting the weight of the raw stock by the weight of the coated paper. (Method 2). Within each set, the coat weights are averaged, and the standard deviations taken. Through a statistical analysis, data outside a confidence limits range are rejected and the new average calculated.

In the ash method, the weight of the ash will be the clay alone, and the amount of latex that was burned off during the ashing has to be added to the weight of ash in order to obtain the coat weight. Since the coat weight is most conveniently expressed in gm/sq.m., the

coat weight of the sample in gm per area of sample used has to be multiplied by a factor to be converted to gm/sq.m.

In the second method, the difference between the weight of the coated paper and the weight of the raw stock will give the coat weight of the sample. Again, this coat weight has to be multiplied by the same factor to obtain the coat weight in gm/sq.m.

Plots are then made as follow:

1. coat weight versus machine speed using method 1
2. coat weight versus machine speed using method 2
3. coat weight versus samples taken at a given speed; only samples taken out at the initial speed, the final speed and the one in between, viz, 500 fpm; 1700 fpm and 1100 fpm are used for this plotting.

Each of these plots includes data from the two blade pressures used (1 pli and 3 pli).

EXPERIMENTAL DATA AND RESULTS

Table I

Coat weight in gm/sq.m. @ 1 pli and using method 1

Speed fpm	Coat weight	deviation
500	7.4765	.1908
700	7.9260	.2641
900	8.4248	.1409
1100	9.9696	.0954
1300	12.3088	.2971
1500	14.7800	.4151
1700	8.1566	.1795

Table II

Coat weight in gm/sq.m. @ 3 pli and using method 1

Speed fpm	Coat weight	deviation
500	6.9621	.1149
700	7.0534	.0632
900	7.4305	.1348
1100	7.5558	.1511
1300	7.6326	.2165
1500	8.1085	.0715
1700	8.1240	.1239

Table III

Coat weight in gm/sq.m. @ 1 pli and using method 2

Speed fpm	Coat weight	deviation
500	6.8979	.4054
700	6.9667	.4688
900	8.5350	.6992
1100	10.5992	.5676
1300	13.6996	.4644
1500	16.0422	.7522
1700	7.6216	.4804

Table IV

Coat weight in gm/sq.m. @ 3 pli and using method 2

Speed fpm	Coat weight	deviation
500	7.3828	.5336
700	6.9529	.5179
900	6.8937	.4650
1100	6.6903	.5045
1300	7.8182	.4643
1500	9.1445	.5132
1700	9.3199	.3960

FIG 1

SPEED VS COATING WEIGHT

METHOD 1

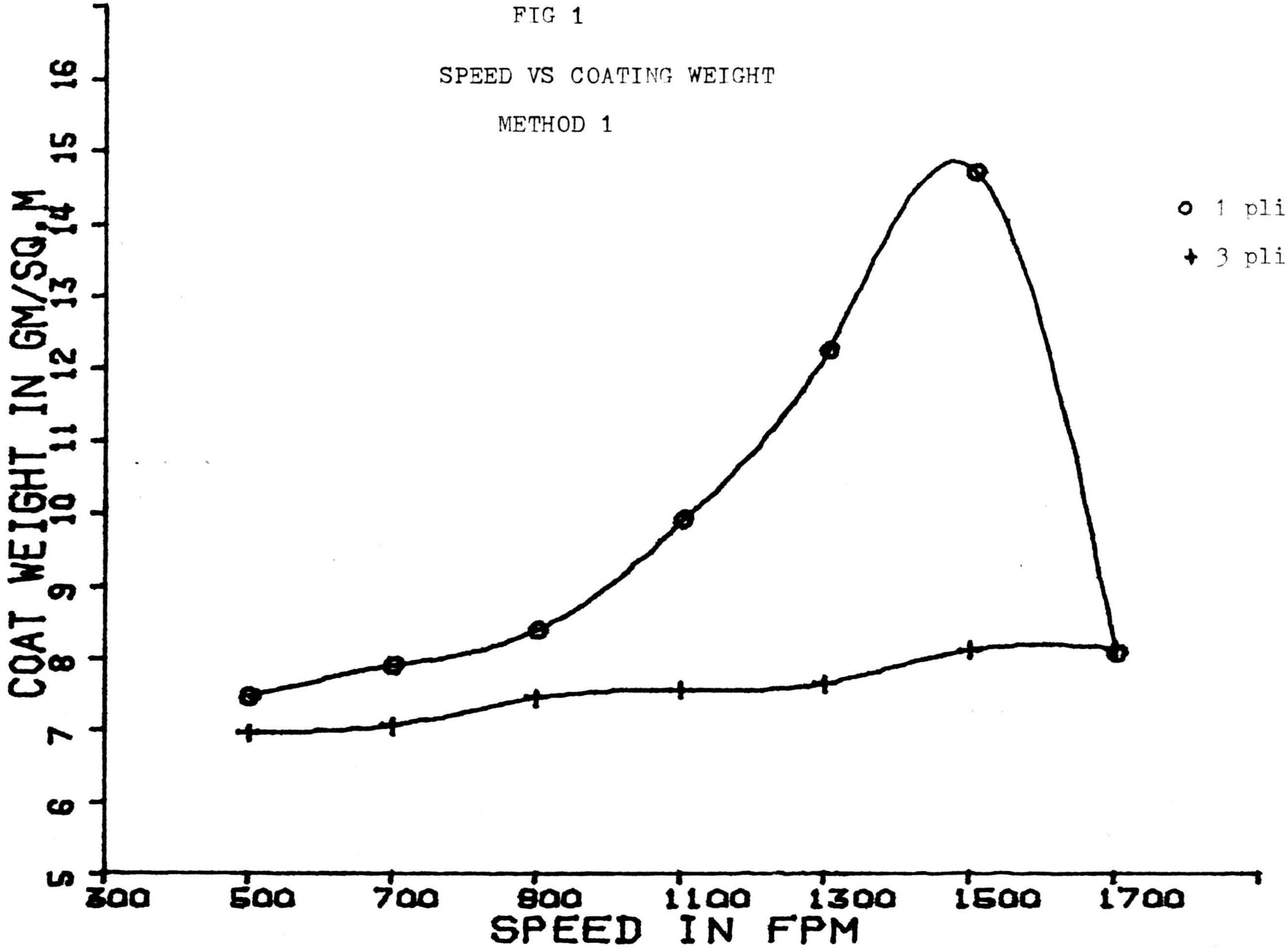
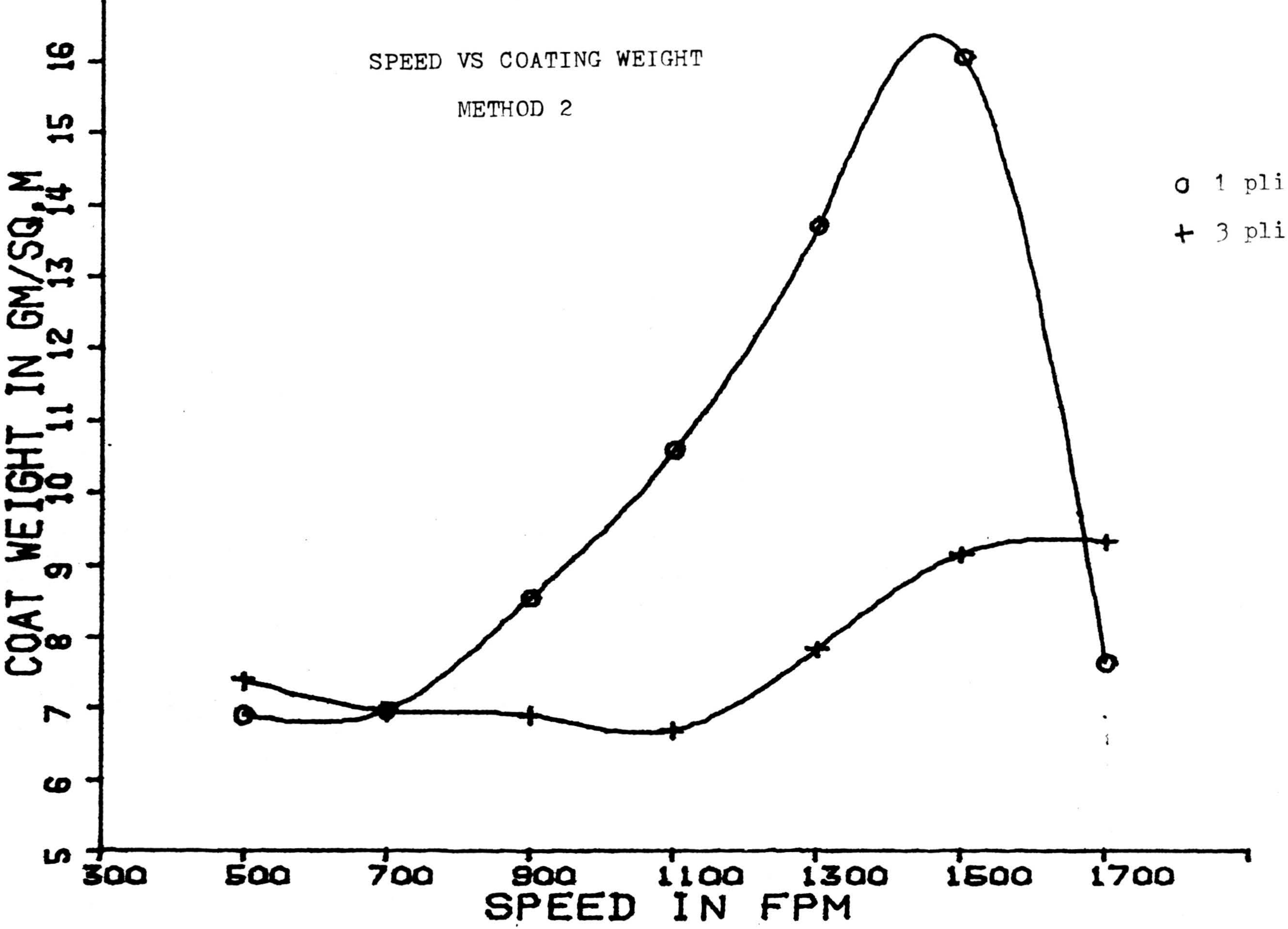


FIG 2


SPEED VS COATING WEIGHT
METHOD 2
COAT WEIGHT IN GM/SQ.M
5
6
7
8
9
10
11
12
13
14
15
16
300
500
700
900
1100
1300
1500
1700
SPEED IN FPM
o 1 pli
+ 3 pli

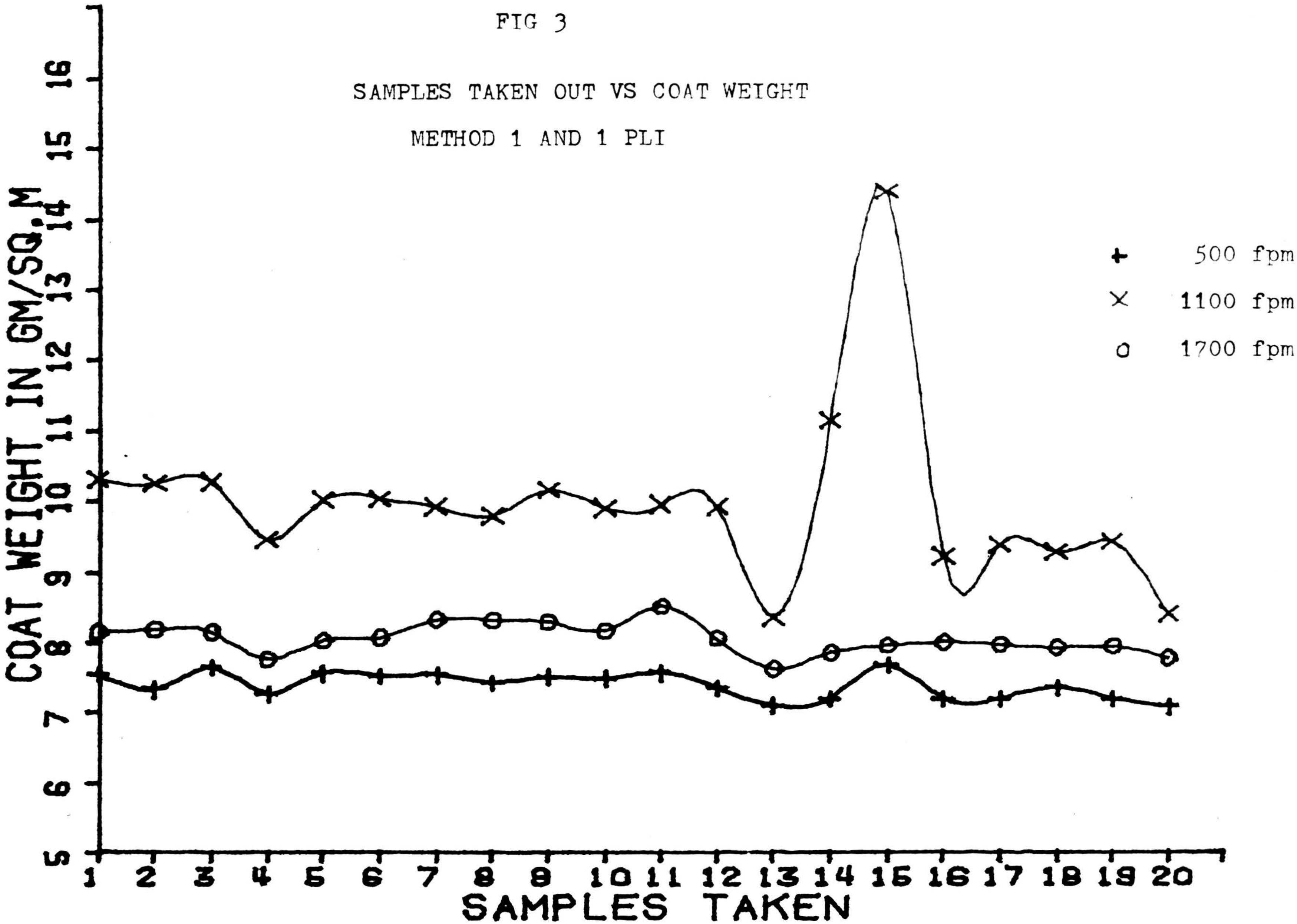
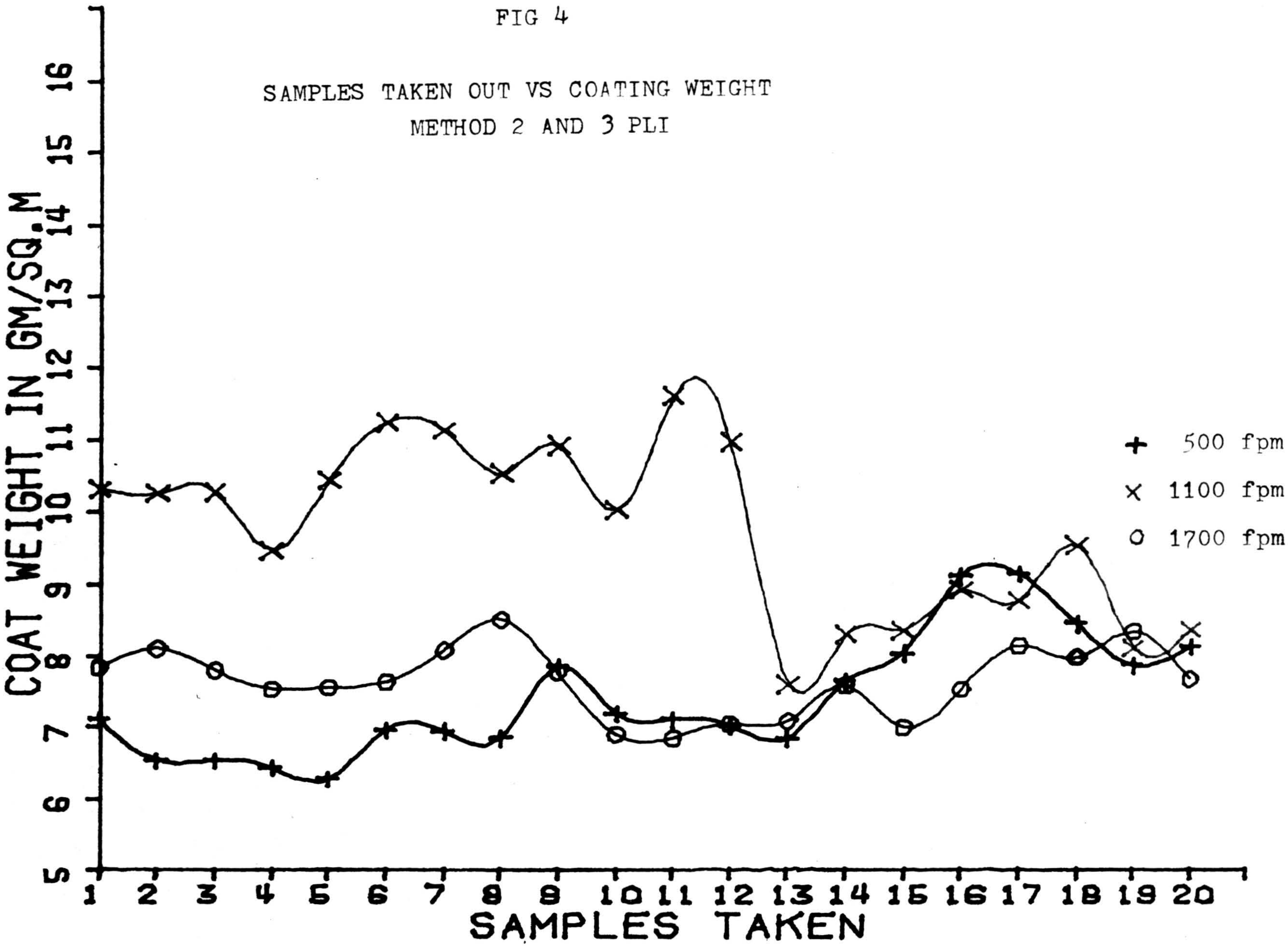


FIG 3
SAMPLES TAKEN OUT VS COAT WEIGHT
METHOD 1 AND 1 PLI
COAT WEIGHT IN GM/SQ.M
SAMPLES TAKEN
500 fpm
1100 fpm
1700 fpm
5
6
7
8
9
10
11
12
13
14
15
16
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FIG 4

SAMPLES TAKEN OUT VS COATING WEIGHT
METHOD 2 AND 3 PLI



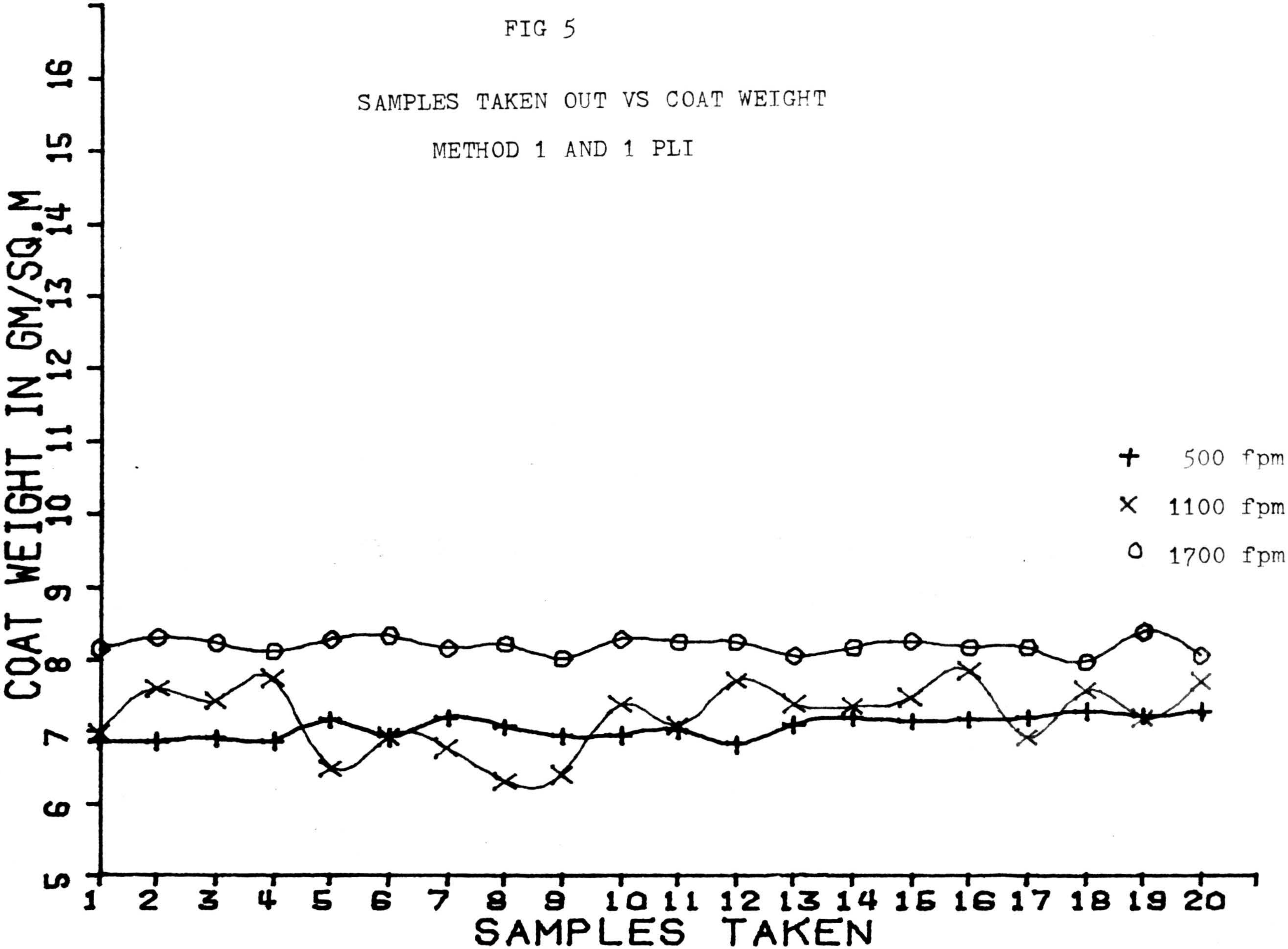


FIG 5

SAMPLES TAKEN OUT VS COAT WEIGHT

METHOD 1 AND 1 PLI

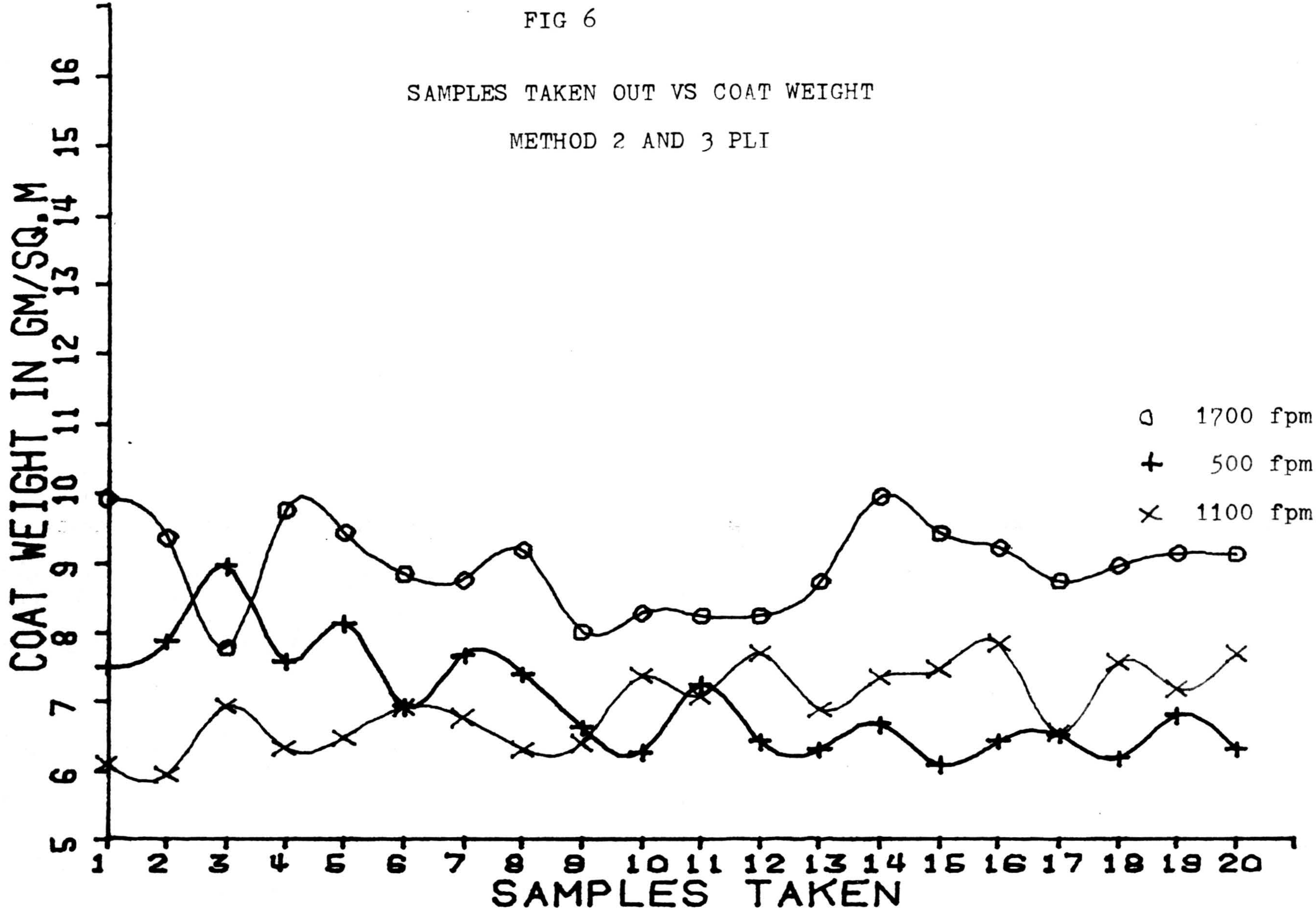


FIG 6

SAMPLES TAKEN OUT VS COAT WEIGHT

METHOD 2 AND 3 PLI

DISCUSSION

As mentioned previously, the two main phenomena governing the coating weight variation are: the hydrodynamic forces and the viscoelastic forces. These two forces are functions of the speed of web as suggested by the two equations outlined earlier. As the paper web travels through the blade during the operation, it creates a force which tends to lift up the blade. The faster the speed, the greater will be the force, and in fact this force is proportional not linearly but to the square of the speed of travel. It could be easily understood then that at considerably low blade pressure, the variation due to a change in speed will be vary observable even at low speed. However, at higher blade pressure, the increase in coat weight due to an increase in speed will be less effective.

Besides the hydrodynamic forces, nevertheless, there is the viscoelastic force, which acts at an angle normal to the blade, that influences the coating weight variation.

Again, as pointed out earlier, this force is a function of the shear rate, the viscosity of the coating color as well as the speed of the web. Since we are not comparing coating colors used, the viscosity of the color is only a function of the speed. Once again, the speed of web plays another role in the second governing factor. The proportionality of the viscoelastic force to the speed of the web is, at this time, linear.

It could be concluded then, that for a fixed coating color and with the other operation conditions like blade angle and blade pressure set at constant, we can predict the amount of coating at a particular speed if we know the relationship between the two. A look at the variation of coat weight due to a change in speed is thus essential. There will be regions, however, where there is great uncertainty in the relationship. This is when the opposing force to the blade pressure is just enough to lift up the blade. At this point, the coat weight is chiefly determined

by the absorbence of the base sheet and the viscosity of the coating color at that point.

Figs. 1 & 2 display the feature of coat weight variations as the web speed is increased from 500 fpm to 1700 fpm. Fig. 1 represents data obtained from method 1 and Fig. 2 for method 2. The two plots represent coat weight variations with respect to machine speed at blade pressures of 1 & 3 pli respectively.

With 1 pli blade pressure, the coating weight is seen to increase with speed up to 1500 fpm and it drops suddently at 1700 fpm. The pattern of the graph representing the same plot but using different method is similar for the 1 pli pressure but displays a difference for the 3 pli pressure. The coat weight variation at the region from 900 fpm to 1300 fpm is just the opposite in the two cases. This indicates that there might be an uncertainty or a large deviation in the data itself at this region. Such deviations can be a result of the unstability of the coating action and

this unstability is so great that it influences the variation with respect to speed to quite a significant extent.

In order to understant this deviations within a sample more clearly, samples were taken out at this region together with those at 500 fpm and 1700 fpm to check the variability of the coat weight within the given speed. Figs. 3-6 represent data for methods 1 & 2 respectively with a blade pressure of 1 pli. On Fig. 3 we would see that the data on both the 500 fpm and 1700 fpm samples show little variations in coat weight. However, quite a big variation is observed with the 1100 fpm samples even if the three points at 12, 13 and 14 are neglected. Here, not only the 1100 fpm samples give such deviation, both the 500 fpm and 1700 fpm samples show deviations in their latter part of the graph. However, the degree of deviation is considerably less than that with 1100 fpm. The data in other samples together with their deviations and averages are shown in appendix IV.

Figs. 5 & 6 represent data for methods 1 & 2 with a

blade pressure of 3 pli. Again, the large deviation associated with the 1100 fpm samples is observed. Pretty consistent values are obtained for both the 500 fpm and 1700 fpm samples. Situations are quite different, however, in method 2. Large deviations are observed in all three sample graphs. This might indicate an inefficiency of the method itself rather than the samples alone.

CONCLUSION

We have discovered, with the aid of experimental results, that in a coating operation, hydrodynamic forces and viscoelastic forces are present at all times and are the main governing factors for the coat weight variations. It is also noted that these two forces are functions of the machine speed and their relationships as suggested by the two equations stated earlier are valid. In the low blade pressure operation, the change in coat weight with respect to speed is rapid and great due to the fact that this low pressure can easily be upset by the hydrodynamic and viscoelastic forces. At a higher blade pressure operation, however, the change in coat weight is slow and steady and can be explained similarly.

Besides increasing the hydrodynamic and viscoelastic forces, an increase in speed of web will set a shorter time interval available for coating penetration. At low speeds of operation and high blade pressures, this effect

is insignificant in comparison to the one affected by the hydrodynamic and viscoelastic forces. However, at very high speed and extremely low pressure, since the two forces are so large that the blade is actually lifted up and the only factor for the coating weight variation is the absorbence of the paper itself. At this time, the time interval available for the penetration of coating color is important. The sudden drop of coat weight at the very speed (1700 fpm) can be explained by this phenomenon if not due to other factors. However, this is not necessarily valid since there is only one data point for consideration. If for even higher speed, the coat weight is still dropping, we can then conclude that the variation is due to this effect.

In comparing the two methods used, the data ontained through the ash method are quite consistent in comparison to the weight subtraction method. This is especially true if the basis weight of the raw stock has itself a very large deviation. The ash method has an advantage of being

independent of the variations in the weight of the raw stock. However, in experiments like this, the consistency in the basis weight of the raw stock is extremely important.

RECOMMENDATIONS

Only the part on the change in speed varying the coating weight is discussed. Putting other variables like viscosity of coating color, additions of additives and solid levels into consideration will give a clearer picture to the mechanism of blade coating.

As pointed out in the discussion section, whether or not the drop of coat weight in the 1700 fpm region is due to the proposed theory still need to be confirmed. It is recommended that a couple more samples beyond the speed of 1700 fpm should be taken and their coat weight weight noted.

ACKNOWLEDGEMENT

I acknowledge gratefully the helpful suggestions of my thesis advisor, Professor J. Kline and the assistance he provided in the whole project.

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APPENDIX I

Equipment

1. Pilot coating machine
2. Kneader
3. Mixer
4. Storage tank
5. pH meter
6. Brookfield viscometer
7. Hercules Hi Shear viscometer
8. Solids tester
9. Balance

Materials

1. #2 HT Clay (predispersed)
2. 638 Dow Latex (48.5% solids)
3. Ammonia
4. Acetic acid
5. Base stock

APPENDIX II

Coating Formulation:

Materials	Dry Weight	Wet Weight	Parts
#2 HT Clay	300#	400#	100
Latex 638 @48%	57.6#	120#	20
Water	-	57	
Total	357.6#	597#	

APPENDIX III

Weight of base stock in gm/sample size

RAW STOCK

1.3203
1.3162
1.3322
1.3197
1.3102
1.3186
1.2834
1.3008
1.3198
1.2900
1.3284
1.3103

1.3125 (average)
0.0140 (standard deviation)

Weight of base stock in gm/sq.m. = Weight of base stock in gm/sample size x 55.1093

APPENDIX IV*

A. (1 pli blade pressure & method 1)

500 fpm	700 fpm	900 fpm	1100 fpm	1300 fpm	1500 fpm	1700 fpm
7.5431	7.7084	8.5489	10.0230	12.3996	14.8726	8.1355
7.3295	8.0597	8.3215	9.9265	12.8110	13.9082	8.1768
7.6395	7.6464	8.4761	9.9265	12.3169	14.2732	8.1424
7.2615	7.9820	8.3490	10.0988	12.8126	15.2790	7.7496
7.5569	8.1838	8.4661	10.0161	12.8680	15.1275	8.0184
7.5155	7.7426	8.3490	10.0368	13.0402	14.8175	8.0596
7.5325	7.6232	8.4248	9.9128	12.0551	14.8295	8.3145
7.4191	8.0941	8.5764	9.7888	12.4409	14.8932	8.3008
7.5018	7.5569	8.3120	8.3490	12.2205	14.8038	8.2801
7.4742	8.3741	8.3947	11.1250	12.4960	15.0448	8.1561
7.5569	7.7980	8.1975	14.3698	12.4615	14.1950	8.5005
7.3364	8.0872	8.7417	9.2170	12.5102	14.6590	8.0459
7.0954	7.1826	8.7761	9.3755	12.5235	14.4176	7.6050
7.1849	7.5844	8.3215	10.1539	12.1376	14.4247	7.8324
7.6671	7.6602	8.5695	9.8921	12.2619	14.7629	7.9426
7.1918	7.5638	8.4292	9.9404	12.1516	15.2239	7.9909
7.1918	7.4742	8.8658	9.9196	12.8031	15.5476	7.9564
7.3432	7.6602	8.4661	8.1631	12.4201	14.8519	7.9081
7.1918	7.7704	8.6762	9.0930	12.8840	14.6321	7.9289
7.0746	7.7566	8.5250	9.2515	12.6131	14.5764	7.7566
7.4765+	7.9260	8.4248	9.9696	12.3088	14.7800	8.1566
.1908¢	.2641	.1409	.0954	.2971	.4151	.1795

* All tabulated weights of paper coating and standard deviations are in gram/square meter

\+ Average of the best 12 samples

¢ Standard deviations of the best 12 samples

APPENDIX IV (cont)

B. (3 pli blade pressure and method 1)

500 fpm	700 fpm	900 fpm	1100 fpm	1300 fpm	1500 fpm	1700 fpm
6.8611	6.9920	7.3746	6.9765	7.6189	8.1010	8.0390
6.8680	7.0952	7.5638	7.5918	7.5706	8.1010	8.1561
6.9024	6.9369	7.3711	7.4122	7.3846	8.1115	8.2389
6.8680	6.9645	7.3778	7.7291	7.7842	8.0390	8.1561
7.1572	7.0780	7.6878	6.9794	7.6809	8.2144	8.1492
6.9231	7.0402	7.3711	7.1557	8.0666	8.2181	7.9495
7.1918	7.0540	7.3228	6.8967	7.4672	8.1286	8.3698
7.0609	7.1504	7.5431	7.3778	8.0390	8.2179	8.0390
6.9299	7.1535	7.5155	7.3364	7.4604	8.0460	8.1355
6.9438	7.0852	7.4052	7.4535	7.5982	8.1321	8.2940
7.0195	7.0509	7.1366	7.8324	7.4398	8.2429	8.2181
6.8198	7.0284	7.4880	6.9094	7.4811	8.2598	8.1010
7.0952	5.8008	6.9094	7.5500	6.6576	7.9495	8.2664
7.1849	5.9862	6.9782	7.1780	6.7561	7.8255	8.3215
7.1366	6.0896	6.7440	7.6809	7.0058	7.9251	8.1424
7.1572	5.7108	7.1298	7.5155	6.8405	7.9475	8.1975
7.1780	7.0675	6.8198	7.6392	6.9851	8.0666	8.0046
7.2744	5.7934	7.0540	7.4191	6.9714	8.0735	8.2664
7.2124	6.8855	6.6406	7.5912	6.9645	7.7944	8.2250
7.2744	7.0646	7.2055	7.8669	6.8818	8.2429	8.2320
6.9621	7.0534	7.4305	7.5558	7.6326	8.1085	8.1240
.1149	.0632	.1348	.1511	.2165	.0715	.1239

APPENDIX (cont) IV

C. (1 pli blade pressure & method 2)

500 fpm	700 fpm	900 fpm	1100 fpm	1300 fpm	1500 fpm	1700 fpm
7.1091	6.9162	8.3821	7.5830	12.6530	16.5547	7.8255
6.5304	7.5169	8.3380	8.2938	14.0307	15.3864	8.0900
6.5304	7.8531	7.4728	8.3490	13.0498	16.4169	8.1424
6.4257	6.9107	8.6190	8.9111	13.7662	17.4585	7.7496
6.2714	6.7730	9.0049	8.7623	13.7552	16.4280	7.6444
6.9603	6.2825	8.8064	9.5394	14.2567	15.8989	7.6216
6.9438	6.7950	7.3846	8.1065	14.0087	15.9650	8.0624
6.8501	6.9768	8.3600	8.3600	13.3914	15.6178	8.4923
7.8420	6.2163	9.2638	9.2638	14.0417	16.1689	7.7593
7.1923	7.1752	9.7378	9.4181	13.9480	15.9154	6.8886
7.1036	6.6627	7.8034	8.3931	13.3804	16.4996	6.8335
7.0154	7.5224	8.9938	8.8340	14.1134	14.1960	7.0374
6.8446	8.2553	8.8907	10.3054	13.7000	15.5958	7.0760
7.6326	7.9688	8.6682	10.2613	14.5212	14.4831	7.5720
8.0349	8.6411	8.6686	10.2778	14.1740	16.2631	6.9878
9.1096	8.1616	9.1812	9.4622	14.9676	15.8328	7.5168
9.1426	9.0489	9.3410	10.4431	13.7937	15.8824	8.1286
8.4482	7.5444	9.2363	10.0468	13.9480	15.4966	7.9687
7.8641	9.0379	9.2528	9.9128	12.6530	16.0864	8.3325
8.1231	8.1176	9.5449	9.7888	13.6394	15.2707	7.6610
6.8979	6.9667	8.5350	10.5929	13.6996	16.0422	7.6216
.4054	.4688	.6992	.5676	.4644	.7552	.4807

APPENDIX IV (cont)

D. (3 pli blade pressure & method 2)

500 fpm	700 fpm	900 fpm	1100 fpm	1300 fpm	1500 fpm	1700 fpm
7.4049	6.2935	7.7539	6.0951	7.8476	8.6081	8.7293
7.8751	7.2689	6.8887	5.9408	8.3601	8.6532	9.9472
8.9553	6.9548	7.0705	6.9383	8.0129	8.6466	9.4237
7.5775	6.5194	6.3706	6.3265	8.2884	8.6742	9.2088
8.1396	7.1752	6.7619	6.4808	7.7373	8.5254	8.7293
6.9273	7.1532	6.2494	6.9162	7.6161	9.3906	8.9498
7.6712	7.3791	7.4287	6.7647	7.9908	9.5228	9.1261
7.3957	8.1341	6.3045	6.3045	8.6246	8.8891	9.1151
6.6352	7.2028	7.0209	6.3872	7.2744	9.5064	9.8921
6.2604	6.4919	6.5304	7.3626	7.6216	9.8976	9.5945
7.2469	6.3816	7.4728	7.0705	7.8611	10.0023	9.6882
6.4147	6.4753	6.8721	7.6932	7.5830	9.4182	9.4347
6.2990	6.9438	6.8060	6.8776	7.7649	8.9553	9.9142
6.6737	7.2910	7.4728	7.4508	7.6657	8.9608	9.3631
6.0786	7.5775	8.1176	7.5886	7.6877	8.9167	7.7649
6.4202	7.1366	7.5610	7.0926	7.7704	8.9112	9.7488
6.5029	7.7704	6.5525	6.5360	8.5144	9.0600	8.2664
6.1722	6.6241	6.1508	7.6822	7.1532	9.7488	8.3215
6.8005	7.4949	8.7238	7.1642	7.6437	9.1040	8.1424
6.3045	7.9028	7.1366	8.3380	8.2058	9.2914	8.1975
7.3828	6.9529	6.8937	6.6903	8.8182	9.1445	9.3199
.5336	.5179	.4650	.5045	.4643	.5132	.3960