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THE EFFECTS OF INCREASING SOLIDS
CONCENTRATION IN AIR KNIFE
COATINGS FOR BOXBOARD

by

Merri G. Onofrio

A Thesis Submitted
in partial fulfillment of
the course requirements for
the Bachelor of Science Degree

Western Michigan University
Kalamazoo, Michigan
December, 1982

ABSTRACT

The purpose of this thesis was to determine whether high solids concentrations may be applied to air knife coatings for boxboard. Considerations were the effects of high solids on coat weight controllability and final sheet properties.

The study was conducted on a pilot air knife coater using coatings at 56-62% solids and containing .2 to .6 parts per hundred CMC as water retention aid. Finished sheet properties evaluated included brightness, gloss, smoothness, IGT pick strength, K & N ink absorption and glueability.

It was determined that solids levels up to 58% could be efficiently run providing machine speed did not exceed 500 fpm. While high solids showed no significant effect on brightness, gloss or smoothness; pick strength, ink absorption and glueability all decreased.

Key words:

High-solids
Air-knife
CMC
Rheology
Water Retention
Boxboard

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INTRODUCTION

One of the major consumers of energy during the manufacture of paper or paperboard is the operation of removing water from the sheet. For coated grades, this includes energy necessary to dry the coating. The water content of a coating is therefore, an important aspect when considering the total drying energy required. It has been shown¹ that even a 1% rise in solids content of a coating reduces the amount of water which must be removed by 3-4%. The economy of high solids is obvious.

However, there are certain problems encountered with high solids coating.¹ The coating may become shear-thickening, which may result in an intolerably high coat weight at high shear rates. Secondly, the water retention of the coating must be considered. Water loss at high solids may be disastrous because of the subsequent rise in viscosity. Also, the properties of paper coated with high solids coatings will change from those obtained with the same coating formulation at lower solids concentrations. Attempts have been made to resolve these problems, but only in regards to blade coaters.

There has been a growing interest by paperboard manufacturers to investigate the possibilities of high solids coatings. Board is commonly coated with an air knife, which because of lower shear dynamics, requires the coating to be more fluid than for blade coaters. This normally requires the coating to be lower in solids concentration. Previous studies on high solids blade coating has demonstrated that by the use of certain components, a coating can be formulated at higher solids and still maintain good runnability. The purpose of this study is to investigate the possibility of coating paperboard with solids levels above those traditionally found with air knife application.

THEORETICAL DISCUSSION

The ability to successfully coat at high solids concentration is dependent on many factors.² The four major factors are: (1) ability to receive or prepare coating at high solids, (2) the elimination or control of interactions between the pigment and the adhesive, (3) the control of rheological properties in order to maintain coater operability and good runnability, and (4) water retention.

Obtaining a high solids coating requires the highest possible dry content during the dispersion stage. Dispersion is normally performed at 50-60% solids. This is impractical for high solids coating preparation because components added following pigment dispersion are often mixtures containing up to 80% water. Dispersion, therefore should be made at 60-75% solids which may not be possible with certain types of dispersers. The high solids content may also demand a longer pigment addition time.

Rheology

The viscosity of a coating effects the amount that adheres to the applicator roll. It also effects the force required to meter off excess coating whether by blade or by air-jet. Subsequently, the viscosity is significant for coat weight control as this is directly proportional to the volume flowing to the metering device.¹

Reduction of viscosity in high solids coatings results from the elimination of pigment/binder interaction. This in turn depends on the degree of reactivity or carboxylation present in the adhesive. Coatings containing a polymer dispersion of "low reactivity" have the potential to be prepared at the highest solids levels because they have the lowest viscosity.³

In terms of rheological properties of a coating, experience has shown that coating colors must have suitable flow properties at very low and very high shear rates. "The shear rate can vary from that of gravity flow in recirculation to 10^6 sec^{-1} or more at the doctor blade. At low shear rates (e.g., 60 rpm Brookfield) the maximum operable viscosity is in the 2000-7000cP range."⁴ In the high shear rate range, observations at intermediate rates (e.g., 10^3 - 10^5 sec^{-1}) indicate that the operable range is of the order of 40-200 cP.

It is common to find that a coating is pseudoplastic at low shear ranges and then becomes dilatant at high shear, especially for high solids coatings. In a study conducted on "Rheology of High Solids Coatings,"¹ the high solids coatings were tested with a Brookfield and with a cone-plate viscometer which allows shear rates up to $20,000 \text{ sec}^{-1}$ to be reached. Since this range is still considerably lower than found at the actual coating head, additional measurements were made with a capillary viscometer, which gives shear rates of the magnitude of 10^6 sec^{-1} .

Measurements made at high shear rates with the cone-plate viscometer indicate that the tested coatings were dilatant, and that the shear-thickening effect is more pronounced at the highest solids levels. Measurements using the cone-plate viscometer at low shear rates showed shear-thinning behavior. Low shear Brookfield measurements also indicated shear-thinning. Capillary viscometer measurements showed that the coating colors were generally shear-thickening, and that the viscosity at the high shear rates were very high.

One particular study was performed⁴ investigating the effect that additions of small amounts of hydrocolloid have on the rheological behavior of high solids blade coatings. The coating formulation in this case consisted of

90 parts No. 1 clay, 10 parts of precipitated calcium carbonate, and 12 parts dry SBR latex. Hydrocolloids used were carboxymethyl cellulose, hydroxyethyl cellulose, sodium alginate and soy protein. Usage levels based on pigment were 0.6% protein and 0.3% CMC, HEC, and sodium alginate.

With respect to rheological behavior, the upper portion of the Hercules "up-curve" indicated slight dilatency in the highest solids level (66%) for HEC and protein formulations, but continuing pseudoplasticity in the CMC and sodium alginate coatings.

Capillary viscometry was also used to extend the shear rate range. The Hercules up-curves all showed a moderate degree of pseudoplasticity between the shear rates of 4.5 and $9.1 \times 10^3 \text{ sec}^{-1}$, whereas the capillary values showed significant dilatency in the range of 10^4 - 10^5 sec^{-1} for all coatings except the CMC color. The CMC coating showed only slight dilatency. "Operable effects of the hydrocolloids during blade coating, assessed in terms of maximum operable solids, showed CMC and sodium alginate to be the most effective."

In a study concentrating on the rheological properties of coating colors at high shear rates,⁵ a small segment was devoted to the study of high solid ranges (63-66%). The study was again, based on blade coating.

The coating formulation for the study consisted of: 100 parts Kaolin clay, 11 dry parts SBR latex, 0.4 parts pyrophosphate and experimental additions of 0.1 and 0.3 parts sodium alginate. Solids levels were 65-68%.

The major finding applicable to this study was that dilatency appears at 10^4 sec^{-1} for coating containing sodium alginate, and at shear rates greater than 10^5 sec^{-1} , the coatings became pseudoplastic, similar to the effects found from CMC.

Due to the fact that most of the previous studies performed on high

solid coatings were related to blade coaters, the predictions and theories regarding rheology may not hold true for air knife. There is a possibility, however that general behavior may be similar, especially in regards to the rheological effects of the hydrocolloids. In addition, the maximum experimental solids for the blade coating studies were as high as 70% and no less than 64%. Since air knife coatings are generally formulated between 45 and 50% solids, the experimental range for this study will be substantially less. Evaluations will be performed in the 52-62% range.

It should also be noted that dilatent behavior encountered during the blade studies was most pronounced at solids levels greater than 63%. Since the highest solids level that will be attempted on the air knife is 62%, dilatency may not be a significant factor.

Water Retention

Water retention, the last and possibly most significant factor to be considered, is defined as the capacity of a coating to retain water during the coating process.

"The water retention must be associated with the general rheological performance, especially for high solids coatings."¹ If water is lost too quickly at high solids concentrations, the viscosity increases dramatically and a conversion may take place from shear-thinning to shear thickening.

Since a latex of "low reactivity" will be used in the experimental high-solids coatings, there may be a need for a component which promotes water retention. CMC has good binding strength and beneficial effects on rheological properties. It also creates water retention.

Coatings with inadequate water retention have the tendency to develop a "filter cake", i.e., a layer of coating that when applied, immediately drops

its water content into the sheet. This creates a crusty surface coating that will not meter off easily or level out smoothly. One interesting finding from a study on hydrocolloids conducted by E. J. Barber⁴ showed that small decreases in solids concentrations of a blade coating significantly decreased the water retention time. This is in complete contrast to theories held by those who have worked with high solids coatings. Barber's assumption is that by decreasing the solids, the voids between particles increased, thus making it easier for the continuous phase to pass through to the basestock. This indicates that there may be no need for CMC as a water retention aid at the highest solids concentrations.

In a study describing the optimum conditions for air knife coating boxboard,⁶ it was stated that the most satisfactory results seemed obtainable with coatings at the lowest solids levels (48%). However, findings made on rheological behavior, viscosity, water retention and general runnability of high solids blade coatings suggests that, with the use of low-reactive binders and small amounts of hydrocolloids, it may be possible to coat boxboard at solids levels above those traditionally found in air knife applications.

Effects on Finished Properties

One may be confused as to whether going to higher solids concentration would be an advantage or a disadvantage because of the large amount of contradictory information found in literature to date.

A table formulated by T. C. Vanya⁹ illustrates this conflict clearly and is reproduced in Appendix I. The table shows a breakdown of conclusions by author of the changes in coated paper properties as application solids are increased.

For example, in a study conducted by D. Eklund¹, gloss diminished substantially by increasing solids on sheets calendered on a 10 nip super-calender. Eklund assumes this occurs because of a lower degree of orientation of clay platelets, a phenomenon he suggests is related to the shear-thickening tendencies of the coating. Eklund adds that the decrease in gloss could also be due to a higher binder content in the surface. Contrary to this, is a study showing that increasing solids increases gloss.³ This was concluded on blade coating prepared with calcium carbonate for both calendered and uncalendered sheets. The conclusion was that the high-solids produced a closer-packed coating with a smoother surface.

Probably the most agreed upon effect of high-solids coatings is reduced binder migration. Higher solids has been found to lower the mobility of the continuous phase because of a reduced void area. This may improve the binder efficiency allowing lower levels of use.⁷ In turn, the lower levels may improve brightness, opacity and surface gloss development.

Another effect of reduced binder migration may be a decrease in K & N ink absorption. It must be specified that the effect may be opposite, if the coating, when formulated at lower solids levels, allows the binder to migrate to the surface. In this case, an increase in K & N ink absorption might be seen from a higher-solids coating.

Binder migration is also related to IGT pick strength. A lower degree of binder migration can increase pick strength because of improved uniformity of the binder throughout the coating layer. It has indeed been shown that increasing solids concentration increases IGT pick strength.⁹

Coat weight, a major interest when coating with high solids concentrations, generally increases with increasing solids. In addition, increased machine speed increases coat weight. Machine speed limits should therefore be

of major concern due to "industry's" desire to run at the highest level of productivity. Increasing CMC concentration up to .6 pph was shown to decrease coat weight due to a combination of its effect on rheology and water retention. Additions of greater than .6 pph had only a minor influence.¹

STATEMENT OF THE PROBLEM

The major obstacle preventing industry from running at high-solids concentrations is loss of coat weight controllability due to high viscosity and perhaps, dilatency. Since cost reduction is an ever-constant objective in coating, no amount of energy savings possible can balance the cost of over-coating. It is therefore, essential to optimize the formulation in order to eliminate factors causing high coat weight. Since alkali-swellable or highly carboxylated binders are advised against due to their viscosity building characteristics, a problem with water retention may also be encountered. Low water retention leads to filter cake formation which in turn destroys surface smoothness and gloss.

The objectives of this thesis are as follows:

1. Determine the upper solids limit that can be efficiently run on an air knife coater.
2. To determine whether CMC, the most highly appraised hydrocolloid may be used as a water retention aid.
3. To improve the understanding of the effect that application solids has on finished sheet properties.

EXPERIMENTAL PROCEDURE

The experimental procedure consisted of two parts: (1) a laboratory study of the basic coating formulation to determine the "best" combinations of solids and CMC, (2) trial evaluations of the high solids coatings on the pilot air knife coater at Western Michigan University.

Laboratory Study

The purpose of the lab work was to determine acceptable formulations based on viscosity requirements. It was desired to obtain a viscosity between 250-450 cP as measured with a Brookfield Viscometer (100 rpm No. 3 spindle).

The formulation consisted of:

1. 80% No. 1 clay (Englehard Spray Satin)
 2. 20% Anatase TiO_2 (DuPont-LW)
 3. .1% TSPP
 4. 20 pph styrene butadiene latex (Dow - 620)
 5. .2-.6 pph CMC (Hercules 7-L low viscosity)
 6. 1.7 pph insolubilizer
 8. Ammonia to adjust pH
 9. Distilled water
- (See Appendix I for detailed formula instructions.)

In order to reduce experimental error through formulation, five gallons of clay slip containing clay, dispersant, TiO_2 and distilled water were dispersed at 70% solids using a laboratory Cowles dissolver at 3500 rpm. Five hundred millileters of slip were extracted for each coating and mixed at low speed with latex, CMC, insolubilizer, ammonia and more distilled water to obtain the various solids levels and CMC concentrations. Solids levels examined in the lab were 56, 58, 60, and 62% with .6, .4 and .2 pph CMC for each.

Initially, CMC was used in a 3% solution. The advantage of this method

was easy mixing with clay slip and latex. However, it was difficult and time consuming to prepare 3% CMC. Therefore, a "wetting" technique was used instead by making paste with the CMC and isopropyl alcohol. The appropriate amount of paste was added directly to 500 milliliters of pigment slip and mixed for ten minutes. Brookfield viscosity was measured for each coating (Table I).

Pilot Plant Trial: Materials and Procedure

Five coatings were chosen for the pilot coater, four being those found to be within the viscosity acceptance range during bench-work.

The fifth coating contained five parts experimental protein and 15 parts SBR latex. It was decided to include a protein coating in the experiment because there was some question to whether a coating having SBR-only as a binder could meet glueability specifications. The protein coating was formulated at approximately 56% solids.

Basestock used was .015" caddystock manufactured by James River, Kalama-zoo. The board had been slightly sized by application of starch to its top side during production. Topliner brightness ranged between 52.2° and 55.5°.

Coat weight target during the pilot trial was 5.0 lb./1000 sq. ft. Variations made on the machine during the run were: (1) speed, (2) coater oven zone temperatures. Air knife pressure was kept constant at 3.5 psi.

Coat weight was determined for each run by inserting a "slip-sheet". Slip-sheets are standard light-weight sheets of paper taped on each end and applied to the top surface of the uncoated web immediately ahead of the coater. The slip-sheet is then retrieved at the reel and weighed. Initial basis weight and the basis weight after coating were then used to get immediate coat weight measurements. A more accurate method for determining coat weight was later performed by ashing the samples and calculating ignition losses.

Once the coating trial was completed, 15" x 15" samples from each run were inserted into one nip of a steel roll calender. A target gloss of 60 was desired and one nip was chosen because any additional nips caused blackening. One nip developed 45-58 gloss. Calender pressure was 380 pli.

Physical tests performed on calendered samples were brightness, gloss, K & N ink absorptivity, IGT pick strength and Waldorf glueability using Kellogg's glue. Smoothness as measured by Parker Print-Surf was determined for both calendered and uncalendered samples.

PRESENTATION OF RESULTS

As seen in Table I, laboratory observations made of coatings varying in percent solids and parts CMC showed optimum viscosities for: 1) 56%:.6 pph CMC, 2) 58%:.4 pph CMC, 3) 60%:.4 pph CMC and 4) 62%:.2 pph CMC. Viscosities at this stage were measured with a Brookfield viscosimeter at 100 rpm, number three spindle and 20°C. Target viscosity was 300-400 cP.

Table II shows actual trial operating conditions for the pilot coater. Trial coatings 2A and 2B were theoretically formulated for 58% solids but through error during make-up, turned out to be 56.6% solids. The experiment then compared four coatings at approximately 57% solids having two different CMC concentrations - .4 pph and .6 pph. This error made it possible to determine the effect of CMC concentration on coat weight at constant solids and machine speed. Increasing CMC from .4 pph to .6 pph decreased coat weight by nearly one pound per thousand square feet (Table III).

In regards to general runnability in terms of streaking and blocking, three of the four approximately 57.0% solids coatings ran acceptably. Samples of the 57% coating run at the highest speed (600 fpm) were badly streaked. Coverage for the 60 and 62% coatings were uniform at 400 fpm, with streaking and blocking occurring at 500 fpm.

The initial protein coating formulated for the trial contained the same defoamer found in the four synthetic coatings. When run on the pilot coater, however, it was extremely evident that there was an incompatibility between the defoamer and the protein because "fish-eyes" had formed all over the surface. Subsequently, samples from this run were rejected, and another batch of protein coating was made-up excluding defoamer. Running at 450 rpm and at

55% solids, coverage from the second protein coating was very uniform.

In terms of finished properties, there was not a great deal of change due to increased solids concentrations. Brightness, and gloss were not significantly different. There was no change in smoothness as measured by Parker Print-Surf on calendered samples. On uncalendered samples, however, smoothness decreased with increasing solids. Brightness gloss and smoothness of the protein-coating samples were not significantly different from the synthetic coating with similar solids concentration.

IGT pick strength as measured for both pick and blister show a decrease and then an increase in IGT with increasing solids. The protein coating had very good pick strength.

Glueability between backliner and coating as measured by the Waldorf Glue tester significantly decreased with increasing solids. K & N ink absorptivity showed a corresponding general trend in that increased solids increases ink hold-out. The protein coating exhibited glueability equivalent to the 56.6% coating. Absorptivity for the protein coating was much higher.

Apparent viscosity as measured by the Hercules Rheogram at 4400 rpm shows definite increases in viscosity with increased solids (Table 4). In addition, through analysis of both upcurve and downcurve, increasing application solids increases the degree of thixotropy. Rheogram curves of the protein coating indicate that its rheological behavior at 55.3% solids is very similar to the synthetic coating at 61% solids/.4 pph CMC.

Analysis of the coatings by the optical efficiency procedure developed by the BRDA shows a slight increase in optical efficiency with increased solids. Optical efficiency of the protein coating was significantly less than the synthetic coatings.

TABLE I
LABORATORY OBSERVATIONS

<u>Target % Solids</u>	<u>Actual % Solids</u>	<u>CMC</u>	<u>*Viscosity</u>	<u>pH</u>
62	61.4%	.8 pph	977 cP	7.0 (No NH ₃)
62	61.4%	.6 pph	805 cP	7.9
62	61.6%	.4 pph	710 cP	8.4
62	61.6%	.2 pph	342 cP	8.6
60	59.6%	.6 pph	601 cP	8.2
60	60.4%	.4 pph	430 cP	8.4
60	59.5%	.2 pph	214 cP	8.0
58	57.7%	.6 pph	438 cP	8.0
58	58.0%	.4 pph	312 cP	8.4
56	56.8%	.6 pph	382 cP	7.7

Brookfield
*100rpm No 3 spindle
20°C

TABLE II
TRIAL CONDITIONS

<u>Trial #</u>	<u>Solids</u>	<u>CMC</u>	<u>Speed</u>	<u>AKP</u>	<u>Oven Temperature</u>		
					<u>Zone 1</u>	<u>Zone 2</u>	<u>Zone 3</u>
1A	56.8%	.6 pph	550 rpm	3.5 psi	300°F	300°F	300°F
1B	56.8%	.6 pph	450 rpm	3.5 psi	200°F	250°F	275°F
2A	56.6%	.4 pph	450 rpm	3.5 psi	200°F	250°F	275°F
2B	56.6%	.4 pph	600 rpm	3.5 psi	275°F	300°F	300°F
3A	(Experimental protein coating with defoamer did not work well due to incompatibility of the two components. Data rejected.)						
3B							
4A	61.0%	.4 pph	400 rpm	3.5 psi	200°F	275°F	275°F
4B	61.0%	.4 pph	500 rpm	3.5 psi	275°F	300°F	300°F
5A	62.1%	.2 pph	400 rpm	3.5 psi	200°F	275°F	275°F
5B	62.1%	.2 pph	500 rpm	3.5 psi	275°F	300°F	300°F
6A	55.3% (Protein/SBR)		450 rpm	3.5 psi	200°F	275°F	275°F

Run 6A contained no defoamer.

TABLE III

TEST RESULTS: PILOT COATER TRIAL

<u>Solids/ CMC</u>	<u>Speed</u>	<u>Coat Weight</u>	<u>Brightness/ Gloss</u>	<u>PPS-10</u>	<u>IGT</u>		<u>Glue</u>		<u>K & N</u>	<u>X50 78</u>	
					<u>Pick</u>	<u>Blister</u>	<u>Time</u>	<u>Force</u>			
56.6/.4	450 fpm	5.3 lbs./MSF	77.1/49.5	2.1/2.7	222	120	40 sec.	400g	14.6	4.30	
56.6/.4	600 fpm	6.2 lbs./MSF	78.9/54.7	1.9/2.7	229	121	42 sec.	412g	11.8	4.30	
56.8/.6	450 fpm	4.4 lbs./MSF	77.0/48.2	2.2/3.3	203	123	46 sec.	450g	14.8	4.26	
56.8/.6	500 fpm	5.3 lbs./MSF	77.1/46.8	2.3/3.1	195	93	46 sec.	450g	13.6	4.26	
61.0/.4	400 fpm	6.2 lbs./MSF	78.2/50.4	2.1/3.7	192	92	49 sec.	325g	13.4	4.01	
61.0/.4	500 fpm	7.0 lbs./MSF	79.0/55.2	2.1/3.4	190	98	52 sec.	312g	11.8	4.01	
62.1/.2	400 fpm	7.9 lbs./MSF	80.1/56.3	2.2/3.5	230	93	50 sec.	375g	12.6	4.14	
62.1/.2	500 fpm	8.8 lbs./MSF	80.8/60.0	2.2/3.3	231	104	52 sec.	375g	12.0	4.14	
GZ	450 fpm	5.3 lbs./MSF	78.0/45.3	2.4/---	235	123	42 sec.	438g	15.4	4.57	

TABLE IV
HERCULES RHEOGRAM VISCOSITY CALCULATIONS

						Degree of <u>Thixotropy</u>
	<u>Solids</u>	<u>RPM (up)</u>	<u>Shear Rate</u>	<u>Viscosity (upcurve)</u>	<u>Viscosity (downcurve)</u>	<u>(Difference)</u>
1	56.8%	1000	20,890 sec. ⁻¹	24.4 cP	19.1 cP	5.3
		2000	41,780 sec. ⁻¹	21.8 cP	18.3 cP	3.5
		3000	62,670 sec. ⁻¹	20.4 cP	18.2 cP	2.2
		4000	83,560 sec. ⁻¹	19.2 cP	18.3 cP	.9
		4427	92,480 sec. ⁻¹	18.3 cP	--	--
2	56.6%	1000	20,890 sec. ⁻¹	21.4 cP	16.8 cP	4.6
		2000	41,780 sec. ⁻¹	19.9 cP	16.6 cP	3.3
		3000	62,670 sec. ⁻¹	18.8 cP	16.8 cP	2.0
		4000	83,560 sec. ⁻¹	18.0 cP	17.4 cP	.6
		4415	92,230 sec. ⁻¹	17.5 cP	--	--
3	61.0%	1000	20,890 sec. ⁻¹	27.5 cP	20.6 cP	6.9
		2000	41,780 sec. ⁻¹	24.4 cP	20.2 cP	4.2
		3000	62,670 sec. ⁻¹	23.6 cP	20.6 cP	3.0
		4000	83,560 sec. ⁻¹	22.3 cP	21.3 cP	1.0
		4418	92,292 sec. ⁻¹	21.3 cP	--	--
4	62,1%	1000	20,890 sec. ⁻¹	29.8 cP	21.4 cP	8.4
		2000	41,780 sec. ⁻¹	29.4 cP	22.9 cP	6.5
		3000	62,670 sec. ⁻¹	29.5 cP	24.4 cP	5.1
		4000	83,560 sec. ⁻¹	27.9 cP	25.5 cP	2.4
		4422	92,376 sec. ⁻¹	26.6 cP	--	--
5	Protein	1000	20,890 sec. ⁻¹	27.5 cP	21.4 cP	6.1
	Coating	2000	41,780 sec. ⁻¹	26.4 cP	21.6 cP	4.8
	@	3000	62,670 sec. ⁻¹	26.7 cP	21.6 cP	5.1
	55.3%	4000	83,560 sec. ⁻¹	23.9 cP	22.0 cP	1.9
		4425	92,438 sec. ⁻¹	22.3 cP	--	--

INTERPRETATION OF RESULTS

Since target viscosity as measured by Brookfield and Hercules was not difficult to obtain with various high solids and CMC concentrations, viscosity did not prove to be a problem in the 56-62% range. At solids levels greater than 62%, this most likely would have been a problem. Since target viscosities were obtainable, the increase in coat weight with increased solids was simply due to the fact that the volume metered onto the sheet contained more solids and therefore gave higher coat weight. High coat weight was not the result of the coating being too viscous.

In regards to the effect of CMC concentration, the reduced coat weight with increased CMC content may have been a result of improved "flowability" of the coating or improved water retention. This indicates that the CMC caused the coating to level-out and meter-off better due to elimination of rapid water loss. It should be noted however, that only one coat weight test by ash was made for each run, and to be statistically valid, more tests would be required to make any statement on the effect of CMC concentration.

IGT pick strength and K & N ink absorptivity indicated that high solids did not reduce binder migration. Since most research has shown IGT to improve, this may be the result of the type of application; namely air knife.

During glue testing it appeared that the glue was penetrating the back-side adequately but not the coated side. This observation, along with K & N ink hold-out, suggests the binder to be concentrated at the surface, a finding that highly contradicts all other research regarding high solids and blade coaters.

The protein coating exhibited very good glueability which was expected.

Correlating with glueability was increased K & N ink absorptivity. It should be noted however, that the protein coating formulated at 55.3% solids performed similarly to the synthetic coating at 57% in terms of glue, K & N and IGT. Lower BRDA optical efficiency may be explained by a lower quality of dispersion. The first batch was incompatible with the defoamer and was thrown out. The second batch was prepared during the machine trial and did not receive the same amount of mixing time.

CONCLUSIONS

In conclusion, it was determined that solids concentration of an air-knife coating containing CMC may be increased up to 58% if machine speed is between 400 and 500 feet per minute. Solids up to 62% may be run providing machine speed is kept at 400 fpm or below.

CMC provided the air knife coating with adequate water retention as indicated by satisfactory smoothness and gloss. Increasing solids requires decreased in CMC concentration.

While increased application solids showed no significant effect on the gloss, brightness or smoothness of calendered samples, IGT pick strength, K & N ink absorption and glueability significantly decreased. This indicates that high solids has an adverse effect on binder migration; opposite of that found in many studies regarding blade coaters.

RECOMMENDATIONS FOR FURTHER RESEARCH

1. Tests on finished sheet properties suggested that binder levels may have been higher than industry may accept; especially in regards to ink absorption. It may be beneficial to investigate high solids at binder levels of 16-18 pph.

2. Coat weight variation created difficulty in correlating properties. Evaluations of solids between 54 and 58% may allow coat weight to be kept constant by varying air knife pressure, thus making the effects of application solids more apparent.

3. It is possible that the highest solids levels would have performed better had the basestock been precoated first. The precoat, possibly a low-viscosity synthetic coating containing binder and clay, may help to reduce filter cake formation by holding the coating up on the surface longer.

4. Effects of high solids could be evaluated more efficiently by performing a series of "pour-ons" in a board mill. This allows the coating to be applied under identical conditions to those used on the machine in question without having to prepare a large batch.

5. Finally, extended research could be conducted in order to calculate the actual amount of energy saved through high solids coatings by calculating energy and mass balances on the coater/coater oven.

APPENDIX I

CHANGES IN COATED PAPER PROPERTIES AS APPLICATION SOLIDS ARE INCREASED

<u>Authors</u>	<u>Energy Demand</u>	<u>Gloss</u>	<u>Brightness & Opacity</u>	<u>K & N Ink Absorption</u>	<u>Pick Resist.</u>
Huggenberger	-	+	=	0	+
Heiser	-	(+)	=	0	=
hershey	-	+	0	+	+
Eklund	-	-	=	<u>+</u>	<u>+</u>
R & D, and Mill	-	+	=	+	+

+ = Increase
 - = Decrease
 = = No change
 0 = Not covered
 () = Slightly

APPENDIX I

COATING FORMULATION - SYNTHETIC

	<u>56/.6</u>	<u>58/.4</u>	<u>60/.4</u>	<u>62/.2</u>
I. With cowles at low speed add:				
Water	80 lbs.	80	80	80
TSSP	85 g	85	85	85
Defoamer	145 g	145	145	145
TiO ₂	37.5 lbs.	37.5	37.5	37.5
Clay	150 lbs.	150	150	150

Increase speed to highest setting and mix 20 minutes.

II. Reduce speed to medium setting. Add:

CMC in Alcohol	510 g	340	340	170
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Mix 10 minutes.

III. Reduce to low speed. Add:

Latex	75 lbs.	75	75	75
NH ₃	Adjust to 8.5	75	75	75
Insolubilizer	3 lbs.	3	3	3
Water	59 lbs.	45	32	20

Mix 10 minutes.

APPENDIX I

PROTEIN COATING FORMULATION

160 lbs. No. 1 Clay

40 lbs. Anatase TiO_2

1 lb. (.4 lb. solids) dispex

97 lbs. H_2O

Mix 30 minutes at high speed.

Adjust pH to 9.0 with ammonia.

Reduce to low speed.

55.6 lbs. (10# dry) Pam gamma-Z.

60 lbs. Dow 620

6% melamine formaldehyde (as received) based on Pam-gamma-Z

Theoretical solids - 58%

Actual solids - 55.3%

APPENDIX II

4000

56.8% .6pph CMC

3000

R P M

0

TORQUE

N=

KALTEC

SCIENTIFIC INSTRUMENT, INC.

BOB	BOB HEIGHT CM	RADIUS CM	INSTRUMENT S
A	5.0	1.95	.00020
B	2.5	1.95	.00040
C	1.0	1.95	.00097

R P M

56.6% .4pph CMC

TORQUE

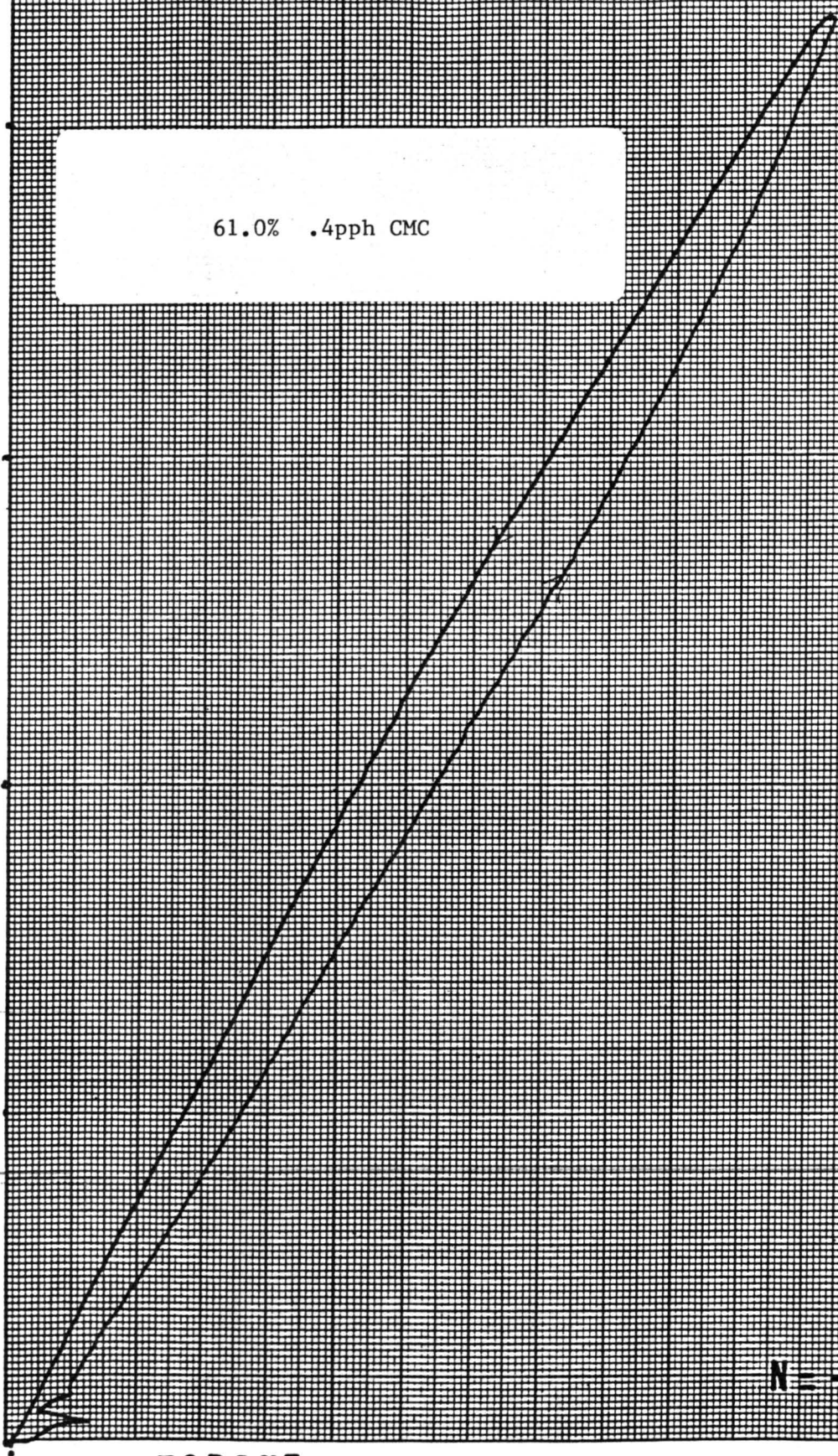
KALTEC

SCIENTIFIC INSTRUMENT, INC.

BOB	BOB HEIGHT CM	RADIUS CM	INSTRUMENTS
A	5.0	1.95	.00020
B	25	1.95	.00040
		1.95	.00000

R P M

61.0% .4pph CMC



TORQUE

$$N = \frac{9.5}{R}$$

KALTEC

SCIENTIFIC INSTRUMENT, INC.
P.O. Box 348 • 2216 Bayview St. • Richmond, B.C. V6X 4K6

BOB	BOB HEIGHT CM	RADIUS CM	INSTRUMENT S	530 RPM
A	5.0	1.95	.00020	2275
B	2.5	1.95	.00040	2275
C	1.0	1.95	.00097	2275

R P M

62.1% .2pph CMC

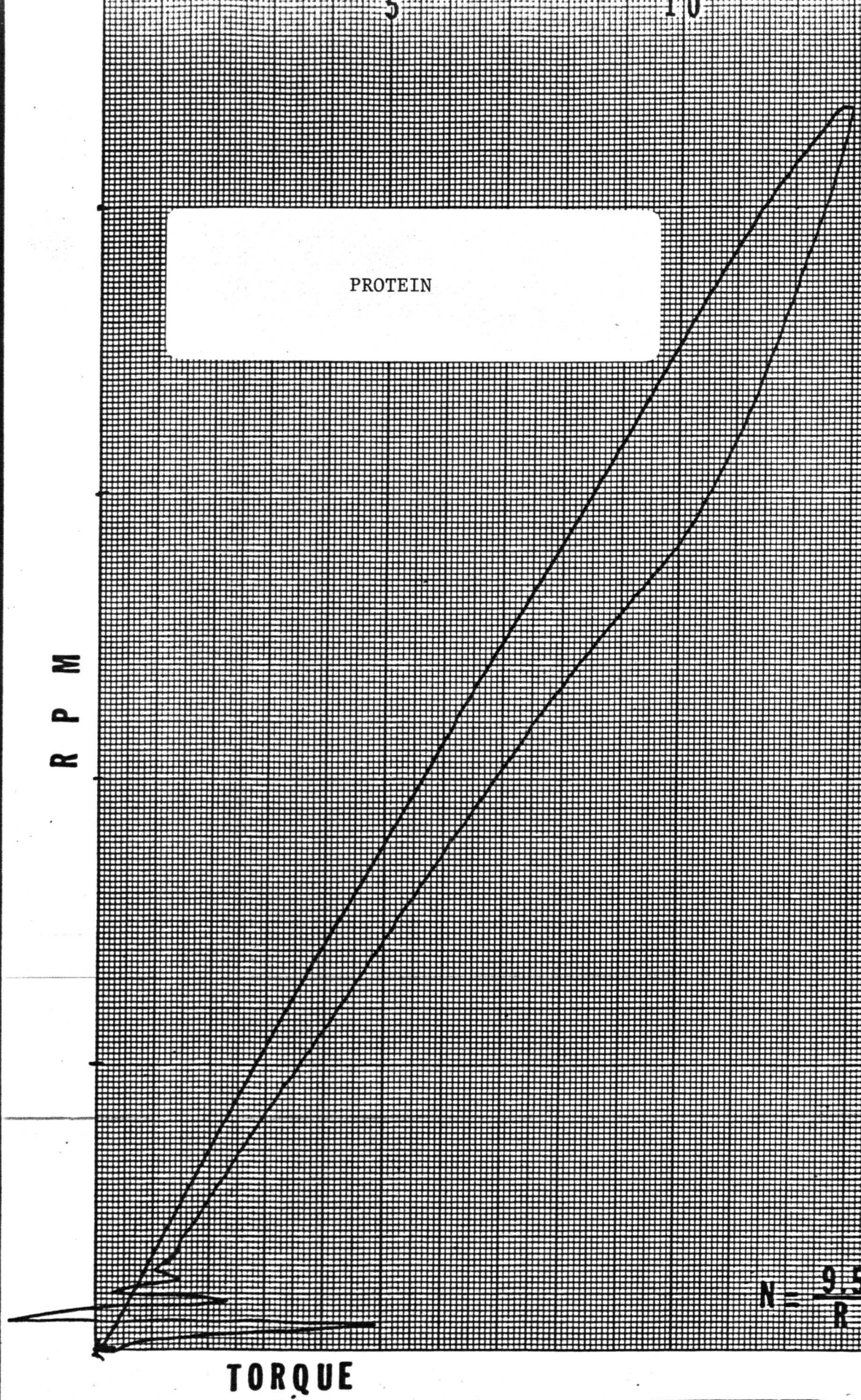
TORQUE

$$N = \frac{9.55 \times T \times R}{R P M}$$

KAITEC

SCIENTIFIC INSTRUMENT, INC.

BOB	BOB HEIGHT CM	RADIUS CM	INSTRUMENT S	550 RPM	MAX (Vol)
A	5.0	1.95	.00020	2275	454
B	2.5	1.95	.00040	2275	454
C	1.0	1.95	.00097	2275	454



KALTEC SCIENTIFIC INSTRUMENT, INC.
 800-218-7272

BOB	BOB HEIGHT CM	RADIUS CM	INSTRUMENT S	SSO RPM
A	5.0	1.95	.00020	2275
B	2.5	1.95	.00040	2275
C	1.0	1.95	.00097	2275

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