4-1987

The Effect of Film Forming Agents in a Size Solution on Silicone Holdout

Michael D. Stang
Western Michigan University

THE EFFECT OF FILM FORMING AGENTS
IN A SIZE SOLUTION ON SILICONE HOLDOUT

BY

Michael D. Stang

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

Western Michigan University
Kalamazoo, Michigan

April 24, 1987

THE EFFECT OF FILM FORMING AGENTS IN A SIZE SOLUTION ON SILICONE HOLDOUT

BY

Michael D. Stang

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

Western Michigan University
Kalamazoo, Michigan
April 24, 1987

TABLE OF CONTENTS

The Effect of Film Forming Agents in a Size Solution on Silicone Holdout

ABSTRACT:

In the production of base papers for silicone coating, one of the most important variables is the holdout capability of the base sheet. The holdout is primarily affected by the surface characteristics of the sheet relating to the smoothness and surface structure.

An experiment was designed to look at the effects of several different commercial film forming agents in a standard size solution on the holdout properties of the sheet. A laboratory size press coater was assembled and used for application of the size solutions. After supercalendering, the sheets were silicone coated with an aqueous silicone solution and then tested for release properties.

Results show that CMC and Kelgin provide the best release properties. By evaluation of both physical and financial properties, the use of CMC would be recommended.

Keywords : Silicone; Release; Sizing; Film Former; Holdout

come in contact with[3].

It is very important that as little silicone be used in the coating process, due to its cost. Usually, .5lb/ream is the standard coating weight applied in a silicone coating system. The more silicone that absorbs, the more that is required to get the same result[4].

BASE PAPER CHARACTERISTICS:

SIZING ADDITION:

The addition of size to the base sheet is primarily intended to improve the smoothness and reduce the permeability of the sheet, both of which help reduce the amount of silicone required during coating.

The amount of silicone used in coating can be reduced by 25% just by adding size to the base paper without changing any of the other parameters[5]. Since the cost of silicone is one of the biggest factors in producing a release grade, it is very important that the sizing solution being used is providing maximum results.

There are many possible chemicals that can be used to treat the base paper before silicone coating, please refer to Table I.

TABLE I: Size Press Additives

Sodium Alginate	Polyvinyl Alcohol
Carboxymethylcellulose	Polyvinyl Acetate
Casein	Bentonite
Nitrocellulose	Acrylic Resin
Styrene Butadiene Latex	Urea-Formaldehyde Resin

There have also been cases where the silicone coating itself is "internally sized" by the addition of thickening chemicals to the coating to help reduce the penetration into the sheet[7]. Each of the chemicals in Table I has a particular difference that makes them unique. This thesis will look for those chemicals that produce the best conditions for silicone holdout.

AIR PERMEABILITY:

The air permeability of the sheet is one of the most used indicators for monitoring production of the base sheet. The longer it takes the air to penetrate, the better the base sheet is for silicone coating[8]. When this variable is not met, the size solution is usually changed to help improve this variable.

Air permeability variable is also affected by the basis weight, fiber content, and the density of the sheet. Supercalendering is usually the last step carried out before the base sheet is silicone coated, so this step allows the producer a last opportunity to refine the sheet characteristics to the needs of the silicone coating.

According to test results[9], the abhesion of the siliconized paper was reduced as the air permeability increases dramatically.

This is one reason why this variable is used to closely monitor the quality of the base paper.

SURFACE ABSORPTION:

The surface absorption of the sheet has an important role in the absorption of the silicone into the sheet, but this role is not as great as that of the air permeability and the smoothness of the sheet, although each of these is connected in some way[10].

On papers that are treated with silicone without size added, this parameter is very important. But, the addition of even a low concentration size solution will help improve this parameter immensely. Surface absorption is particularly important in base papers that are treated with an aqueous silicone solution. From the literature, the air permeability is still considered to have a greater effect on the release properties of siliconized papers than the surface absorption of that paper[11].

SMOOTHNESS:

The smoothness of the base sheet is primarily controlled by the supercalendering of the sheet[12]. The smoothness is directly related to the surface characteristics of the sheet, which is where the layer of silicone will be applied. The rougher the surface, the greater chance there is for non-uniformity in the coating, causing release problems.

The use of sizing will help the smoothness by helping to fill in some of the voids and surface pockets before supercalendering and silicone coating. Most of chemicals listed in Table I have a filming aspect to their chemical nature, which influences this property more than any other.

SILICONE:

Silicone is used to produce release grades of paper due to several of its important characteristics. First, it has a very low surface tension. The surface tension of silicone is lower than that of all other polymers except for some hydrocarbon fluorides[6]. Secondly, the silicone molecule has a low molecule polarity, which is very important to the binding or cross linking of the silicone to the cellulose in the paper.

The general appearance of the silicone molecule is found in Figure 1[13].

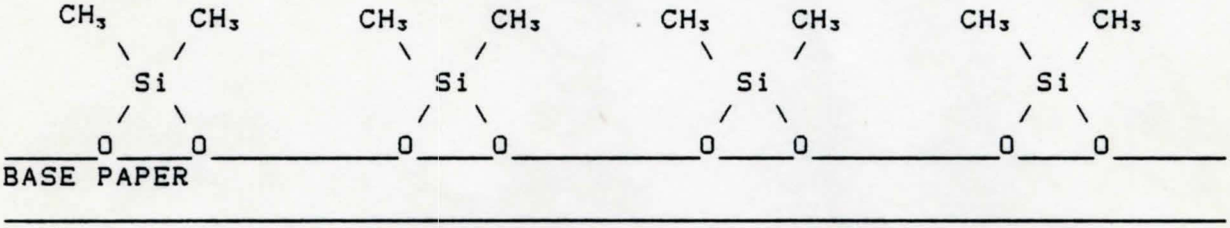
<u>FIGURE 1</u>: Silicone Molecule

```
 R    R    R    R    R    R
 :    :    :    :    :    :
  ----Si--O---Si---O--Si--O---Si--O---Si--O---Si----
 :    :    :    :    :    :
 R    R    R    R    R    R
```

where R represents a methyl, ethyl or phenyl group. Silicones used in paper finishing usually have side chains of methyl groups that are exposed on the surface. The diagram in Figure 2 shows the bonded silicone on the surface, which helps show the

"rejecting" effect that silicone has to adhesive, glue-type materials.

FIGURE 2: Silicone Bonding to Paper



The oxygen atoms in the Si-O-Si bonds form a hydrogen bridge with the substrate, and the methyl groups orient themselves outward from the surface.

The amount of silicone that is applied varies considerably, but the typical coating ranges used are 0.3 - 1.0 g/m^2. The base sheet used is not important provided that the final base sheet has the desired physical characteristics that the silicone requires for proper coating[14].

Some of the general properties of silicones are that they are an intermediate between polymeric and organic substances. They resist extreme temperatures, have good insulating properties, chemical stability, low inflammability, high surface activity, hydrophobic nature and anti-adhesive behavior with various types of adhesives and glues.

The following properties of the organosilicone compounds are utilized in the finishing of paper[12]. The abhesive (anti-adhesive) property, the hydrophobic and surface properties

which counteract the foaming of the saturation baths and coating mixes. The methyl-hydrogen-polysilioxanes, the methyl group silicones, form networks under the action of catalysts and high temperature, forming a "plastic film" on the surface of paper with the abhesion and hydrophobic properties desired. The catalysts usually used are compounds of tin, zinc, zirconium and titanium. The silicone molecules at the surface become oriented to the surface while the methyl groups stick out on the outside. The methyl groups create a very high tension at the inter-phase surface, which disappears in the presence of low surface tension compounds like liquid glues, lacquers, and tacky glues.

SILICONE PAPERS IN GENERAL:

The final silicone coated base sheet is normally used as the base for the application of an adhesive coated label. Please refer to Figure 3 and Figure 4 for further descriptions of the base sheet and composite sample.

FIGURE 3: Exaggerated view of silicone coated base sheet

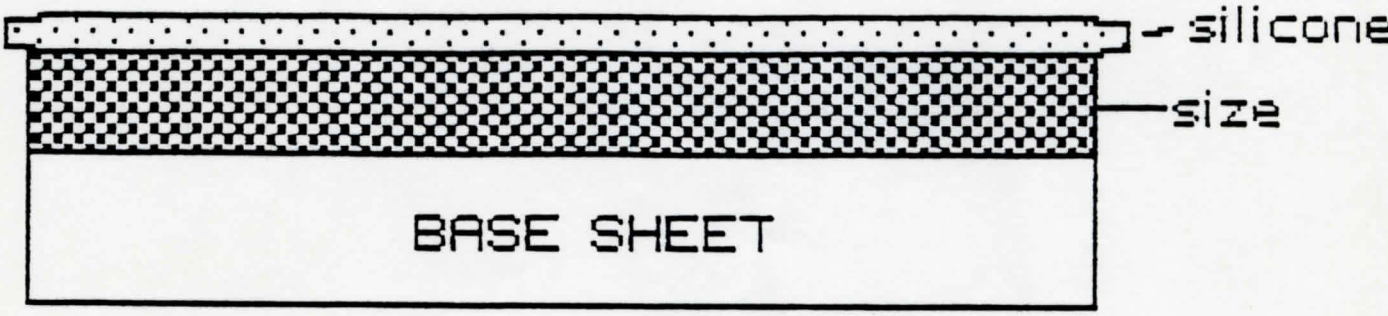
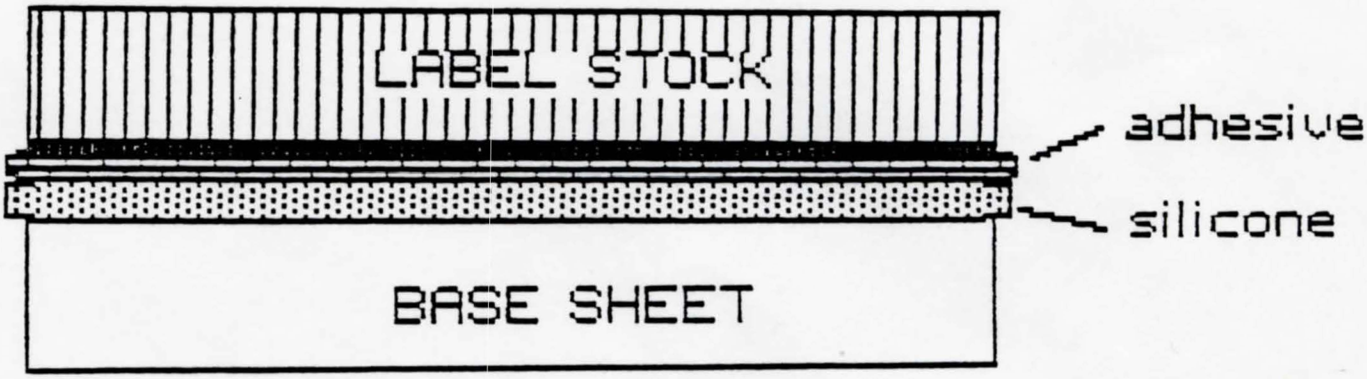


FIGURE 4: Composite Label Example



When looking at Figure 4, which is exaggerated, the importance of the caliper of the base sheet can be seen. In most commercial applications, this composite sample is passed through high-speed die-cut machine and the label is attached to a product while the base sheet is collected and disposed of. Without proper caliper control, the knives may cut to far or too short of the base sheet, causing the entire production line to come to a stop. Thus, caliper control is one of the most important quality control variables in the production of release backing paper.

EXPERIMENTAL PROCEDURES:

Materials:

There were two major materials used for this experiment, the size solution chemicals and the silicone coating components.

The size solutions were composed of a standard starch, PG-280 and were made to 9% solids in all cases. There were 5 film forming agents used, with each one being applied at 1% of the total size solution. Please refer to Table II for specific details.

TABLE II: Composition of Sizing Solutions

Solution #1		Solution #2		Solution #3	
Water	1000g	Water	1000g	Water	1000g
PG-280	90g	PG-280	90g	PG-280	90g
Kelgin MV	9g	PV alcohol	9g	CMC	9g

Solution #4		Solution #5	
Water	1000g	Water	1000g
PG-280	90g	PG-280	90g
PV acetate	9g	Syn-Chem 1010H	9g

After the supercalendering step, the treated sheets and the control sheets were then silicone coated on the Time/Life coater. The silicone solutions used were comprised of the chemical mixture found in Table III.

TABLE III

Silicone	Dow Syl-off 1171	12.6g
	Dow Catalyst 614	.83g
	Water	85.7g

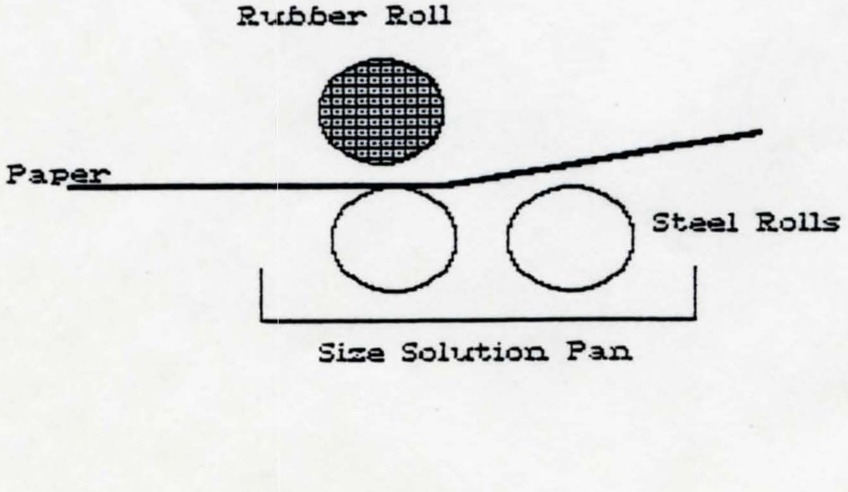
This silicone solution is a water emulsion, that formed a fairly uniform coating on the papers to which it was applied.

Procedure:

An unsized base sheet was obtained from Nicolet Paper in DePere, WI. This sheet is a typical release grade at a basis weight of 41.5 lbs/ream. The samples used were obtained from samples taken before the size press of #3 paper machine. Samples of the typically treated production sheet were used as a control throughout the experiment.

One of the biggest problems to the completion of this experiment was the use of a bench-top laboratory size press coater. This piece of equipment is outlined in Figure 5.

FIGURE 5: Laboratory Size Press Coater



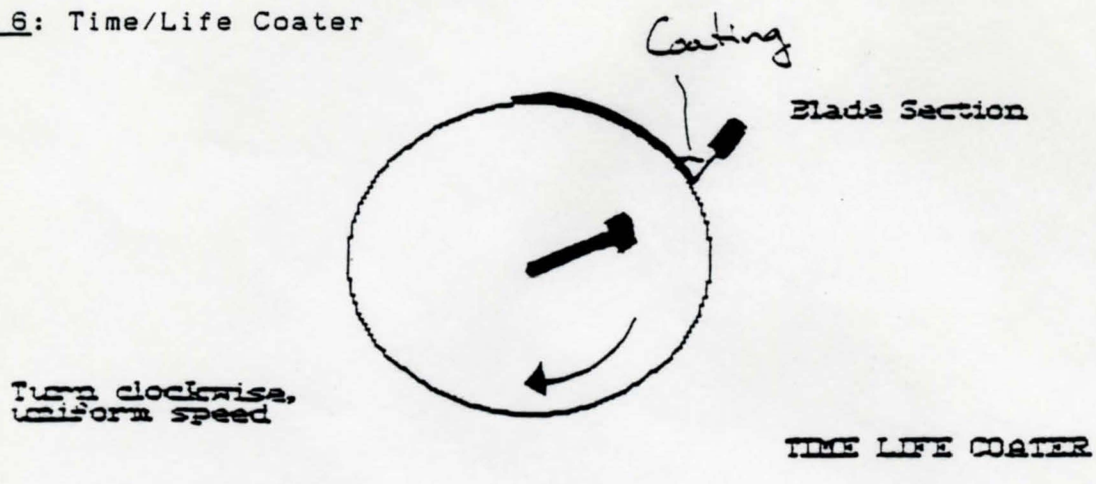
This particular piece of equipment had several pieces missing from its structure, along with the problems of locating an appropriate pulley for its operation. After the tedious task of attaching a pulley to the variable speed motor, an appropriate method of removing the paper sample from the nip was obtained. This was done by the used of a coaterblade and extended handle. The method developed was revised and improved over time by myself, but is not something that could be taught overnight. Through many mistakes, the exact timing of removing the sheet from the roll was found. It involved the "peeling" of the sheet off of the bottom transfer roll and then placing in the oven for drying. Due to the complications of removing the sheet, over 25% of the base sheets coated were either damaged or had to be thrown out due to imperfections in the procedure.

After size was applied, the sheets were then dried in an oven at 150° F for 10 to 15 minutes, after which, they were weighed for coat weight calculations.

After the size solutions were applied, the sheets were then supercalendered on the laboratory supercalender in the Paper Department. The loading on the nip was adjusted to 30 psi and the sheets were passed through the nip 5 times, coated side to the steel, to attain the final caliper desired before silicone coating.

After supercalendering, a silicone solution was applied on the Time/Life coater, which is diagramed in Figure 6.

FIGURE 6: Time/Life Coater



This coater has a bevelled blade under pressure that is held next to the sheet. A uniform volume of silicone solution was added to the dwell area and the sheet was passed through at a uniform rate. The base sheets were attached to the main roll with scotch tape, leaving a tab at the top to remove the sheet from the roll and placed in the oven. The primary concern here is that the silicone is applied at a uniform rate for each of the sheets, and then placed in the oven as quickly as possible to obtain the best curing on the surface. One of the biggest problems is that the determination of the exact coat weight is not possible, due to the initial puddle of silicone on the surface. A 16 square inch sample from the middle of the coated sheet was weighed and compared with the same size sample from a size only coated sheet to obtain the estimated silicone coat weight.

The physical testing of the silicone coated sheets involved two procedures. The first involves a simple rub test with the thumb to check the cure of the coating. In conjunction with this test, scotch tape was applied to the surface, removed, and checked for

exposed fibers. After these steps, a strip of the coated sheet, 2 inches by 2 inches, was cut and a piece of standard 3M masking tape with an acrylic adhesive, 1 inch by 2 inches, was applied. The flap end of the tape and the open end of the paper were placed in the Instron Tensile Tester and the force required to separate the tape from the paper was measured. The lower the value, the better the release properties of the coating.

DISCUSSION OF RESULTS:

The following table outlines the results from testing at all stages of this experiment. The data presented are the mean values from the testing unless otherwise indicated.

TABLE IV: Mean Values for Data Collected

Parameter	CMC	Kelgin MV	Polyvinyl Alcohol	Polyvinyl Acetate	Syn-Chem 1010H
Basis Weight (lb/ream)	40.7	40.7	40.7	40.7	40.7
Raw Caliper (mils)	4.11	4.11	4.11	4.11	4.11
Size Coat Wght (lb/ream)	2.10	2.15	2.16	2.14	2.15
Finished Caliper (mils)	2.61	2.60	2.62	2.63	2.62
Silicone Ct.Wt. * (lb/ream) **ESTIMATE**	2.00	1.90	2.00	2.20	2.25
Rub-off Test ** (operator)	none	none	none	none	none
Release Test (g/in^2) 20 tests	14.98	19.85	39.22	40.52	79.67

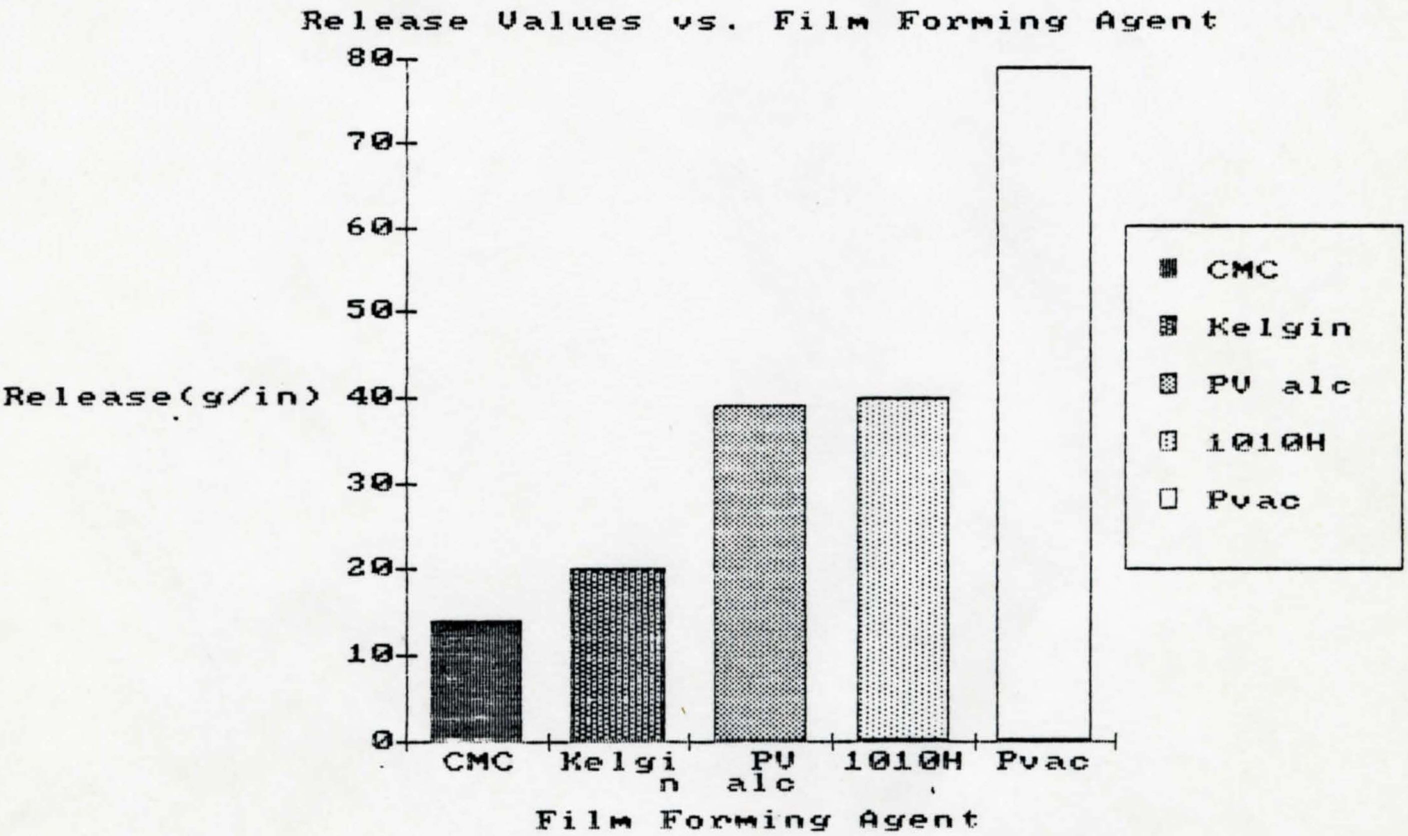
* The silicone coat weight was estimated by cutting a 16 square inch sample from a coated sheet and the same from a sized sheet as the basis. Due to the application of the silicone, a portion of the test sheet had some time to absorb a portion of the silicone.

** The Rub-off test is described in the procedures, with it primarily being an operator test to visually determine the quality of the silicone coating.

NOTE: The supercalendering was carried out on production paper to determine the number of passes to reach the desired caliper. The gloss was checked informally, with no apparent deviations occurring between test solutions.

+++ The results are based on 20 tests for each of the five groups.

FIGURE 7: Comparison of release values to their respective film forming agent



The results from the final data tell most of the story of this thesis. The silicone holdout of the base sheet is dependent on the surface of the sheet, which is greatly affected by the film forming agent used. Thus, the release properties of the sheet will also be dependent on the amount of silicone remaining and cured on the surface after a uniform volume of silicone was applied to the sheet.

From the release values listed in Table IV for the five different solutions tested, the best results were obtained from the CMC film forming agent. In Figure 7, the level of release properties are compared for the 5 solutions. Each of these five solutions provided results that would be considered acceptable for most commercial grades of the paper.

The Kelgin had the second best release value of the group, and when looking at the cost of Kelgin, its financial value becomes very important. The difference in release values is approximately 20% between CMC and Kelgin. The cost of Kelgin is considerably higher than that of CMC:

TABLE V: Cost Comparison of Compounds

Compound	Cost/lb
CMC	$1.03
Kelgin MV	$2.83
Polyvinyl Alcohol	$0.39
Polyvinyl Acetate	$0.94
Syn-Chem 1010H	$2.25 ** estimated

Based on the results, the use of CMC would appear to be a better choice for physical properties and economy.

Since the accurate weight of silicone applied to the sheets could not be calculated, the amount absorbed is not evident. Yet, since the same volume was used, it is assumed that those with higher release values do not have as much silicone on the surface, which is more than likely due to absorption. Since the amount of silicone used means even more savings to the customer, the use of CMC would appear to provide the best surface for silicone hold-

out since the amount of silicone used could be reduced to give adequate or equivalent release with substantial cost savings, based on the parameters of this study.

CONCLUSIONS:

Of film forming agents used, Carboxymethylcellulose, CMC, provides the best silicone hold-out properties and the most cost effective application.

With the use of CMC, the amount of silicone needed could be reduced to give adequate or at least equivalent release in comparison to the other film forming compounds.

RECOMMENDATIONS:

The natural step in the continuation of this experiment is to take the concepts found here to a pilot plant situation or to a limited production application, which is always a difficult task to consider.

With the data produced here, a production setting would help to provide information that would either support or oppose the laboratory results produced here.

LITERATURE CITED

1 Ivanov, S.N., "Paper Technology", Forestry Industry, 1970, p.695.

2 Dengler, W., "The Coating of Release Papers", Coating, No. 6, June 1974, pp. 143-145.

3 Eklund, D., "Coating of Paper with Organic Silicone Solutions", Paperi Puu, 53, no. 12, p. 711-13, (Dec. 1971)

4 Nakamura, Y.,"Release Paper", Central Research Lab, Kekusaku Papers, Japan Pulp and Paper, 8, no. 3, Oct. 1970, pp. 48-51.

5 Petrov, A.P., "Sizing of Paper and Board", Forestry Industry, p. 161, 1974.

6 H. Marwitz, "Silicones in the Paper Industry", Papierverarbeiter 3, no. 6, p. 46-8, June, 1968.

7 Hockemeyer, F., "Use of Silicones in the Paper Converting Industry", Adhasion, 17, no. 7 p. 248-54 (July, 1973).

8 "Silane Paper Treatment", Paper Trade Journal, 167, no. 4, p. 31, (Feb. 28, 1983).

9 Toepsch, H., "Silicones in the Paper Industry", Wochbl.Papierfabr, Vo. 99, no. 11/12, pp. 435-7, June, 1971.

10 Moore, G., "Surface-Applied Chemicals Development", Paper (London) 204, no. 3, p. 22-23 (Sept. 9, 1985).

11 Jones, Darryl, Dow Corning Corporation, Midland, MI.

12 Lauppi, U.V., "Electrocurtain Process", Coating, 17, no. 1, p. 8-10 (Jan. 1984).

13 Farrand, J.C., "Requirements for Base Paper for Coating with Silicone", Pulp and Paper, 51, no. 8, p. 102-5 (July 1977)

14 Marwitz, H., "The Testing of Silicone Release Papers", Pap.Kunstst. Verarb. Vol. 6, no. 9, Sept., 1971, pp. 22-32.

REFERENCES

Baker, Sharron, Fasson Corporation, Quakertown, PA.

"Glossary of Terms used in the Pressure Sensitive Tape Industry", Pressure Sensitive Tape Council, July, 1974.

Grenoble, Morry, General Electric Corporation, Boston, MA.

Howard, D.W., Modern Plastics, 41(3), p. 84, Nov., 1963.

Kaufman, W.J., Modern Plastics, 34, 126 Dec. 1956.

Keil, J.W., Paper Film & Foil Converter, no. 8, p. 34-8, 1958.

Knapp, Lowell, Senior Process Engineer, Nicolet Paper, DePere, WI.

Packaging, 31, no. 368, p. 74-75, 1960.

Panse, Craig, Technical Superintendent, Plainwell Paper, Plainwell, MI.

Smith, David P., Dow Corning Corporation, Midland, MI.

Tishtyenko, A.F., "A New Kind of Release Paper", Bumazh. Prom., No. 1, Jan., 1975, pp. 22-23.