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THE STRENGTH OF CHEMICALLY BONDED NONWOVEN FABRICS AS A FUNCTION OF THE IONIC CHARGES OF BINDERS AND FIBERS

by

Harry S. Kalpagian

A Dissertation Submitted to
the Faculty of the Graduate School at
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Approved by

Melvin H. Hurwitz
Dissertation Adviser

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

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This study compared the tensile strength of chemically bonded nonwoven fabrics as a function of ionic charges of fibers and fiber finishes and of binders and binder emulsifiers. The binders were applied at normal (20%) and low (5%) concentrations; the low binder level was used to avoid possible masking of ionic interactions. In all, 70 different nonwoven fabrics were prepared for tensile measurements.

The means and standard deviations of the tensile data were examined by analysis of variance. The tensiles varied significantly (.05) among the nonwoven fabrics. Multiple comparisons using Scheffé's tests showed which binders differed significantly (.05) from each other. On the basis of rank ordering the results of Scheffé's tests, it appeared that greater tensile strength resulted from ionic interaction between the binders and fiber finishes as well as between the binder emulsifiers and fiber finishes. There was no indication of ionic interaction between the binder and fiber or binder emulsifier and fiber.

These findings are consistent with the knowledge that ionic charges buried in the polymer backbone, such as in the fiber and in the binder, would be inaccessible because of distance and lack of mobility. Conversely, these findings are also consistent wtih ionic interactions found with the fiber finishes and the binder emulsifiers; these are small molecules with mobility.

ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

The manufacture of nonwoven fabrics is the most dynamic and fastest growing segment of the textile industry. A report by Frost and Sullivan, Incorporated predict that the U.S.A. nonwoven fabric market will grow approximately 60% in real terms during the 1978-1988 decade.[1] The report also states fiber consumption will grow at an annual rate of 5.4% for the first five years and diminish to 4.3% for the last five years.

Nonwoven fabrics are used for diaper cover stock, surgical packs and gowns, filtration media, wipes and towels, apparel interlinings (sewn and fusible coated), beddings and home furnishings, carpet components, automotive trunk lining carpets, substrates for coated and laminated products, geotextiles, personal hygiene products, and other industrial uses. These products are produced by one or a combination of the following four basic processes:

1. mechanical entanglement of fibers by needles, or jets of air or water
2. thermal bonding of fibers by point bonding or the incorporation of either binder-fiber or fusible powders
3. spunbonded or spunlaced
4. chemical resin bonding of fibers

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[1]"Growth Predicted for Nonwovens" (Frost & Sullivan, Inc. Report No. 752), Textile Institute and Industry 18 (March 1980):84.

This study is concerned with the last process, chemical resin bonding of fibers, specifically, the bonding of dry-laid webs with acrylic latices. The manufacture of chemical bonded fibers consists of forming a web by either a dry-laid or wet-laid process and applying a latex binder.

Dry-Laid Webs

Dry-laid webs are formed by processing preopened fibers in a conventional card or an air-lay system. Since carded webs are unidirectional, they are usually crosslapped to get some fiber orientation in the transverse direction (figure 1).

Air-laid webs are formed by feeding preopened fibers to a card drum via an inlet aggregate. Due to centrifugal force and an air stream, single fibers are released from the cylinder surface and collect on a moving perforated conveyor screen (figure 2). This forms a continuous web which is doffed.[2] Binders are applied to dry-laid webs by foam, spray, print-bonding, or saturation.

In foam bonding, the latex binder is diluted with air, resulting in a large volume of encapsulated binder solids which are applied throughout the fibrous web. Normally, a foam is comprised of 5-10% water and 90-95% air.[3] Foam is applied by special applicators, nip rolls or an engraved roll. Unless it is applied by padding onto the

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[2] A. T. Purdy, "Developments in Nonwoven Fabrics," in Textile Progress ed. P.W. Harrison. (Manchester, NV: Textile Institute, 1983), p. 15.

[3] Dennis E. Wood, "Aerated Latex Bonding of Nonwoven Fabrics," pt. 1., Nonwovens Industry 11 (May 1980):20.

Web Forming Equipment

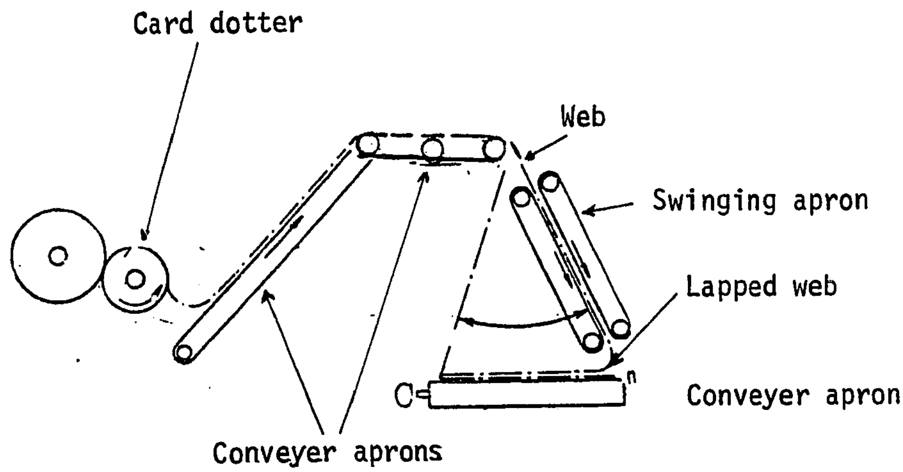

Figure 1. Side view of a cross-lapper

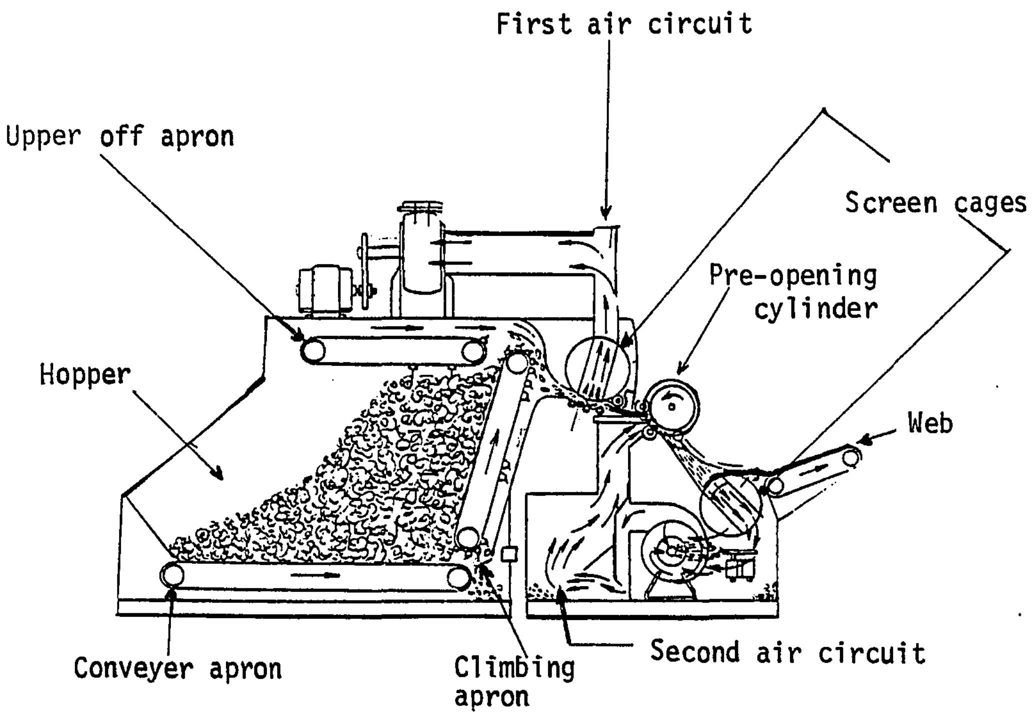

Fig. 2. Rando feeder and Rando-Webber unit

web, the foam is collapsed and drawn through the fibers by a vacuum slot or box located under the moving web, and the web is then dried on heated steam cans.[4]

Spray bonding is generally done on high loft products used for quilting, bedspreads, comforters, air filtration media, and quilted jacket linings to retain bulk or loft required of these products. Low levels of binder solids are sprayed onto the surface of the moving web by either fixed (stationary) or reciprocating spray guns with little or no binder penetration into the fibrous mat. Both sides of the web are treated in separate stages by processing the web in a two or three pass oven.[5]

Print bonding is the application of a discontinuous coating of adhesive applied in a repetitive pattern which does not completely coat or encapsulate the fibers. This results in a product with a soft hand and moderate drape, but relatively low tensile properties.[6]

Saturation bonding is done by impregnating with squeeze rolls or by immersing the dry web held between two screens or between a drum and a screen, and passing the web over a vacuum slot to remove excess binder (figures 3 and 4). The saturated web is then dried, usually over steam-heated cans.[7]

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[4] Ibid.

[5] Personal experience in a production plant.

[6] Purdy, "Developments in Nonwoven Fabrics," p. 50.

[7] Ibid., p. 33.

Web Impregnation Equipment

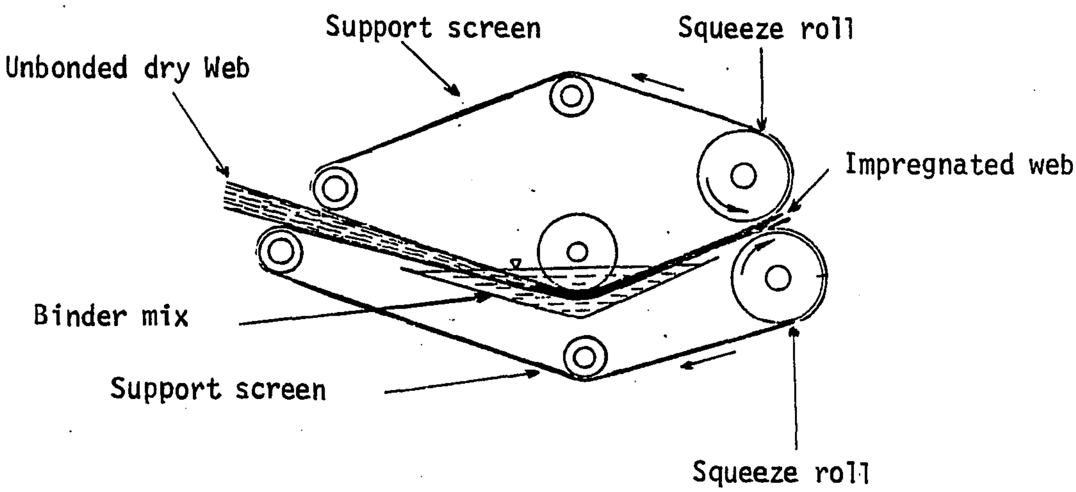

Fig. 3. Rodney-Hunt web impregnation unit

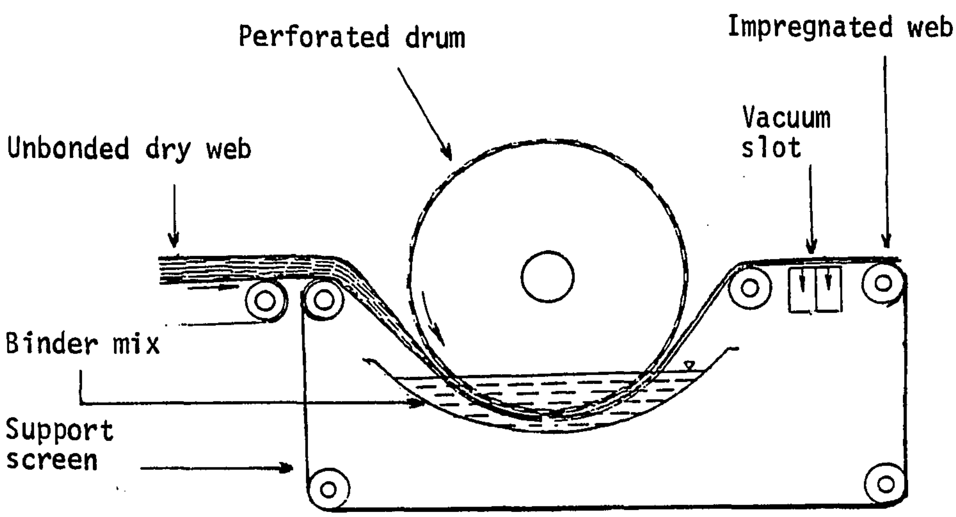

Fig. 4. Vacuum saturator

Wet-Laid Webs

Wet-laid webs are formed on some variation of wet-papermaking equipment such as a Fourdriner or cylinder-forming element or an inclined wire screen.[8] Binders can be applied by wet-end addition which incorporates aqueous polymer emulsions or solvent polymer solutions during web formation and/or the methods used for dry-laid webs.[9] Thermal binder fibers can also be used in place of latex binders. Since these binder fibers have a lower melt point than conventional fibers, they form bonds in the matrix when the web is exposed to heat.

Fibers and Latices

The principal fibers used are rayon, polyester, and polypropylene. Also nylon, acrylic, glass, and cotton fibers are used but to a much lesser degree. Exotic fibers sometimes used are aramid, polyphenolic sulfide, polyphenolic amide, and carbon where unusual strength is required.

The term latex is a broad umbrella that includes all types of polymer emulsions. The major latices used commercially are acrylates, acrylonitriles, polyvinyl acetate and copolymers, polyvinyl chloride and copolymers, vinylpyrolldene copolymers, and styrene-butadiene (SBR). In addition, new polymer emulsions such as modified silicones have been developed that are just making their entry into the market, e.g. ethylene/vinyl acetate, ethylene/acrylic acid.

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[8] Ibid., pp. 43-44.

[9] Ibid., p. 46.

It is estimated that in 1982, the U.S.A. nonwovens industry consumed 170 million wet (85 million dry based on 50% solids) pounds of latex to produce latex bonded fabrics, excluding spunbonded, spunlaced, and wood pulp fibers.[10]

The purpose of the latex binder is to add strength and integrity or resistance to deformation. It is essential to get good bonding of the fibers with the selected latex to achieve desired end results as illustrated in figures 5 and 6. During the bonding of the fibers with acrylic latices, certain ionic charges may be present that need consideration. Ionic charges can be present in the fiber and its finish, in the binder polymer and its emulsifier and in any added surfactant. Based on a search of the literature and questions posed to both fiber producers and binder manufacturers, no report of an investigation has been found relating these ionic charges to the resulting strength of the nonwoven composite.

Statement of the Problem

The purpose of this study was to compare the tensile strengths of chemically bonded webs made with combinations of selected fibers and acrylic latices carrying anionic, cationic, and no electrical charges. The specific objective of the research was to compare the tensile strength of nonwovens as a function of fiber and binder charges, holding physical and mechanical factors such as fiber length and cross section constant.

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[10]Telephone interview with John Starr, John Starr Incorporated, Boston, Massachusetts, 1 March 1984.

Scanning Electron Microscope Views of Well-Bonded Nonwovens

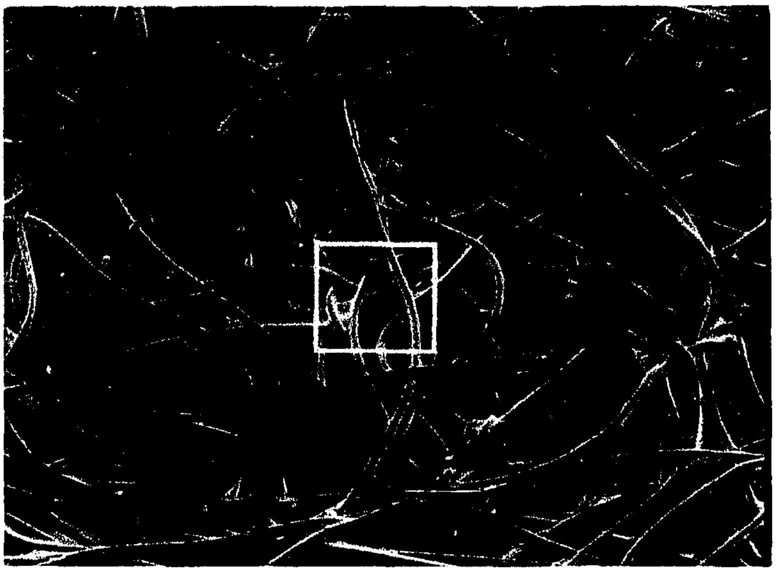

Fig. 5. Magnified 300X

Fig. 6. Section of figure 5 magnified 2000X

Assumptions

In this study, the following was assumed:

1. Fiber orientation of like webs was comparable as they were made on the same machine.
2. Any differences observed in tensile strength between like webs with the same binder would result from the ionic charges involved.

Limitations

This study was limited by the following:

1. The fibers considered were limited to the rayon control--two polyesters, one modified polyester, one polyester copolymer, and two polypropylenes. All but the two polypropylene webs were formed on a laboratory model Rando Webber[R] which yielded randomized webs. The average weight of each was 31.5 grams/yard^2 ± 20%. Because of their coarseness and fiber length, the two polypropylene webs were formed on a plant garnett. This resulted in a unidirectional web with very little transverse (cross-machine) fiber orientation and different weight webs for the two fibers. The average web weight for the regular polypropylene was 38.64 grams/yard^2 ± 8.3% and for the acid dyeable web, 50.99 grams/yard^2 ± 8.8%.
2. Only five commercially available acrylic latices were selected. The charges on the binder polymers and their emulsifiers were respectively as follows:

   Binder A - cationic/nonionic
   Binder B - nonionic/anionic

Binder C - anionic/nonionic
Binder D - nonionic/nonionic
Binder E - anionic/anionic

A cationic/cationic was not commercially available.

3. All webs were padded at 20% and 5% dry add-on based on weight of fiber. This range was selected to show differences that may be masked or hidden by higher add-on levels.

Hypotheses

The following primary null hypothesis was tested:

1. There are no differences in tensile strength among nonwovens bonded with the five binders at equal add-on on each of the seven webs as a function of the ionic charge on the binder and on the fiber.

In the course of testing the primary hypothesis, the following secondary null hypotheses were also tested:

2. There are no differences in tensile strength among nonwovens bonded with the five binders at equal add-on on each of the seven webs as a function of the ionic charge on the binder and the fiber finish.
3. There are no differences in tensile strength among nonwovens bonded with the fine binders at equal add-on on each of the seven webs as a function of the ionic charge on the binder emulsifier and the fiber.
4. There are no differences in tensile strength among nonwovens bonded with the five binders at equal add-on on each of the seven webs as a function of the ionic charge on the binder emulsifier and the fiber finish.

Definition of Terms

The following definitions have been used for this study:

Anionic. An ion, molecule, or chemical substance having one or more functional groups bearing a negative charge.

Cationic. An ion, molecule, or chemical substance having one or more functional groups bearing a positive charge.

Denier. Denier denotes the fineness or coarseness of a fiber. The lower the number, the finer the fiber. Denier is defined as weight in grams of 9,000 meters of a filament yarn or fiber.

Dynes. A metric unit that measures the force required to accelerate one gram of matter one centimeter per second squared. It is expressed as dynes/cm^2.

Elongation. The deformation of a textile fiber or fabric when subjected to a tensile force. It is expressed as a percentage of the length of the test sample held between the jaws of a testing unit.

Emulsifier. A surfactant that helps to disperse and stabilize emulsions.

Fiber spin finish. Generally a water-soluble compound that may be a lubricant or an antistat which is applied to fibers by the fiber producers.

Nonionic. A molecule or chemical substance that bears neither a negative nor positive charge.

Polymer. A chemical compound formed by a chemical reaction in which molecules or a mixture of molecules are combined to form larger molecules that contain structural units of the original molecules.

Scrim. A textile fabric used as support or substrate in a composite or laminate.

Stress-strain properties. The amount of deformation with a given force.

Surface tension. A resultant lateral attraction and downward force that makes the surface of a liquid act like an elastic film or rubber sheet.

Tensiles or tensile strength and tenacity. The longitudinal stress required to rupture a solid material such as a textile fabric.

CHAPTER II

REVIEW OF LITERATURE

Many studies have been made of the contributions of the fiber and binder to the physical properties of a latex bonded nonwoven.[11] Initial investigators focused on the role of the fiber as the major factor regarding the stress-strain properties of bonded webs. Hearle and Stevenson reported on the effects of the anisotropy of nonwoven webs and fiber curl as related to modulus, strength, breaking extension, and fiber orientation.[12]

Not all of the earlier research centered on the fiber as the principal factor influencing stress-strain properties of a bonded fabric. Based on laboratory trials with viscose, rayon, and rubber latex, Michie, Peters, and Taylor concluded that as the binder content is increased, the amount of binder at the fiber crossovers and interstices also increases as well as the strength and stiffness of the fabric up to a maximum value. Additional binder above this value will only increase the thickness of the rubber between the fibers at the

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[11] M. M. Besso, G. E. Gillburg, and D. E. Stuetz, "Contributions of Binder and Fiber to Nonwoven Properties," Textile Reasearch Journal 52 (September 1982):587.

[12] J. W. S. Hearle and P. J. Stevenson, "Nonwoven Fabric Studies. Part II: The Anisotropy of Nonwoven Fabrics," Textile Research Journal 33 (November 1963):888.

crossovers without much effect on tensile strength which would tend to be constant.[13]

In a later study by Hearle and Newton regarding the role of the fiber network as related to the stress-strain behavior of bonded webs, it was reported that the binder had a much greater effect than suspected.[14] When they compared theoretically determined stress-strain curves with those measured on a few nonwoven fabrics, they found good correlation between theory and experiment, especially if the simple network theory is modified by taking into account fiber slippage through the binder.[15]

Zeronian and Wilkinson reported that the more uniform the binder distribution, the more difficult it becomes to delaminate latex bonded fabrics.[16] A study on the migration of binder in fibrous webs during drying found that when binder migrates to the web surface, leaving low levels in the web interior, the fabric will have poor resistance to delamination.[17]

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[13] R. I. C. Michie, R. H. Peters, and W. Taylor, "Nonwoven Fabric Studies. Part I: Properties of Laboratory-Made Fabrics Bonded with Natural Rubber," Textile Research Journal 33 (May 1963):328.

[14] J. W. S. Hearle and A. Newton, "Nonwoven Fabric Studies. Part XV: The Application of the Fiber Network Theory," Textile Research Journal 38 (April 1968):351.

[15] Ibid.

[16] S. H. Zeronian and J. Wilkinson, "Nonwoven Fabric Studies. Part XI: Binder Distribution Effects," Textile Research Journal 36 (October 1966):866.

[17] R. I. C. Michie and J. A. Wilkinson, "Nonwoven Fabrics Studies. Part XII: Observation on Latex Migration in Fiber Webs," Textile Research Journal 37 (June 1967):461.

Hearle and Newton recognized that the physical properties of latex bonded fabrics were dependent not only on the properties of the fiber and the binder but also in their interaction in the web.[18] Since the properties of the bonded fabric are dependent upon the behavior of the individual fibers and their bonds within the structure and due to the difficulties in observing minute areas within a bonded web, Hearle and Newton designed systems of model bonds by joining pairs of individual parallel fibers with a single bond.[19] They found when high strain was applied, either the binders broke down at the binder-fiber interface or the fiber ruptured. There was not a single observation where the binder material itself ruptured.[20]

In one of the latest investigations, the researchers studied not only the contributions of the properties of the fiber and binder but also those of the interfacial properties which included the effects of fiber finish, surface tension of the binder, macroscopic and microscopic binder distribution, and added surfactant.[21] The observations made in this study show that binder conhesive strength may be more critical than binder adhesive strength as a major factor in the stress-strain behavior of a bonded fabric. No evidence was found of fiber

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[18]J. W. S. Hearle and A. Newton, "Nonwoven Fabrics Studies. Part XVI: The Behavior of the Model Systems of Bonded Fibers," Textile Research Journal 38 (May 1968):488.

[19]Ibid.

[20]Ibid., p. 496.

[21]Besso, Gillberg, and Stuetz, "Contributions of Binder and Fiber to Nonwoven Properties," pp. 592-594.

breakage which suggests that either deposition of binder occurred along the nonload bearing fiber surfaces or the cohesive strength of the binder now exceeded the adhesive strength of the binder-fiber interface. They concluded that above a certain add-on level, the cohesive strength will surpass adhesive strength.[22]

In this same study, it was concluded that nonwoven fabric tensile is not affected by the presence or lack of typical fiber finishes, if allowance is made for variations in add-on levels, but the fiber finishes do have an effect on the rate of binder pick-up into, and the amount of binder retained by the web.[23] They also concluded that surfactants can decrease the binders cohesive strength or make the distribution of the binder less load bearing and also change cohesive failure into adhesive failure.[24]

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[22]Ibid., p. 592.

[23]Ibid., p. 593.

[24]Ibid., p. 596.

CHAPTER III

PROCEDURE

This study was designed to measure and evaluate both dry and wet tensile values of acrylic latex bonded nonwoven fabrics made with seven selected fibers and five selected acrylic latices. The webs were padded, air dried, oven cured, and tested. Duplicate sets of fabrics were made with fiber and binder.

The procedure for this investigation is divided into the following: selection and description of fibers, selection and description of acrylic latices, formation of dry webs, bonding of fibers, description of test conditions, and rating of results.

Selection and Description of Fibers

Seven commercially available fibers were selected for this study.

a. One rayon control - fiber nonionic, finish cationic.

b. One modified polyester - both fiber and finish anionic.

c. Two polyesters - both fibers nonionic, both finishes cationic.

d. One polyester copolymer - fiber anionic, finish cationic.

e. Two polypropylenes - regular nonionic polypropylene fiber, finish anionic;
acid dyeable polypropylene - both fiber and finish cationic.

Selection was based on homogeniety of samples among commercially available fibers in terms of denier, luster, length, and finishes. For identification purposes, numerical codes were assigned to each fiber.

A more detailed explanation will be presented under bonding of fibers. table 1 lists the various fibers, their codes, and properties. From this point forward, polyester will be referred to as PE, polyester copolymer as PCP, and polypropylene as PPY. None of the webs was given any pretreatment to remove fiber finish.

Table 1

Codes and Properties of Selected Fibers

				Ionic Charge	
Code	Fiber	Denier x Length	Luster	Fiber	Fiber Finish
1,2, 21,22	Rayon	3 x 2"	Bright	N	C
11,12, 31,32	PE #2	1.5 x 1.5	OB	N	C
9,10 29,30	PCP	1.5 x 1.5	OB	A	C
3,4, 23,24	PE #1	2.25 x 1.5	OB	N	C
13,14 33,34	MPE	2.25 x 1.5	OB	A	A
5,6, 25.26	R-PPY	7 x 6	Natural	N	A
7,8, 27,28	A-PPY	7 x 6	Natural	C	C

OB = Optically brightened
A = Anionic
C = Cationic
N = Nonionic
PE #1 &
PE #2 = Polyesters
PCP = Polyester Copolymer
MPE = Modified polyester
R-PPY = Regular polypropylene
A-PPY = Acid dyeable polypropylene

As shown in table 1, the pairs of fibers, PE #2 and PCP, PE #1 and MPE, and R-PPY and A-PPY are similar in their properties except for the ionic natures of the fiber and for its finish.

Selection and Description of Acrylic Latices

Five commercially available acrylic latices were selected for this study. Table 2 lists the binder polymer, physical properties and codes. Webs of each fiber were padded to yield 20% and 5% dry add-on of each binder (e.g., each bonded web after drying was composed of either 80% fiber/20% binder or 95% fiber/5% binder).

Table 2

Codes and Properties of Selected Latices

Code	% Solids	*Tg ^{0}C	Ionic Charge	
			Polymer	Emulsifier
A	60	-18	C	N
B	60	-15	N	A
C	46.0	- 4	A	N
D	45.5	-14	N	N
E	44.5	- 7	A	A

A = Anionic
C = Cationic
N = Nonionic
*Softening temperature Tg refers to the temperature at which the polymer changes from a glassy or brittle condition to a "liquid" or "rubbery" one.[1]

Formation of Webs

All but the two polypropylene webs were formed on a laboratory model air lay Rando-Webber[R]. The webs were all processed at identical

[1]Paul J. Flory, Principals of Polymer Chemistry (Ithaca: Cornell University Press, 1953), 53.

settings except for adjusting fiber feed to attain a target web weight of 28.35 grams/yd^2. Approximately 15 yards of each web (12" wide) was rolled up in Kraft paper. Fiber orientation in the webs appeared to be typical for this machine--moderately randomized.

Because of their seven inch length, the two polypropylene fibers would have wrapped around the rolls and jammed the laboratory Rando-Webber[R]. Therefore, the two polypropylene webs were processed on a production garnett. The fibers were fed into a hopper and feed rolls, and then directly into the garnett. The discharged web was rolled up in Kraft paper without being cross-layed, producing a fairly uniform but highly unidirectional web with little significant cross-machine fiber orientation. The one-yard square weights of each web are listed in table 3.

Application of Acrylic Latices

Prior to applying any binder to the webs, samples of each web were padded separately with water, water and surfactant, and solutions containing 20% binder solids with 0.20% nonionic surfactant. Based on weight measurements before and after padding, drying, and curing, it was possible to predict the required binder solids needed to get the desired add-on. The observations from these pick-up trials will be discussed later in the results.

The dry-formed webs, supported between light weight layers of thermally bonded polypropylene scrim, were padded with each binder to yield 20% and 5% dry add-on, based on data collected from the earlier

Table 3

Weights of Carded/Unbonded Fiber

Webs on Basis of One Yard^2

Code	Fiber	Grams/Yard^2	± Percent Variation of Weight in Dry Web
1,2 21,22	Rayon	32.40	16.0
11,12, 31,32	PE #2	30.43	10.98
9,10 29,30	PCP	30.59	14.0
3,4, 23,24	PE #1	28.59	9.7
13,14, 33,34	MPE	29.14	8.0
5,6, 25,26	R-PPY	38.61	8.2
7,8, 27,28	A-PPY	50.99	12.1

pick-up trials. Before padding, all webs were conditioned overnight at 72^{o}F ± 2^o and 65% relative humidity ± 2%. Each sample was padded single dip on a two-roll laboratory pad at 30 PSI, the scrim was removed and the treated webs were placed on screens to air dry. The samples were turned over at two-minute intervals until dry. After conditioning overnight, all the samples, exclusive of the polypropylenes, were cured at 320^{o}F for five minutes in a Despatch oven. Due to their low melt index, the polypropylene fabrics were cured at 270°F for 2.66 hours.[2] The cured samples were conditioned overnight and reweighed to determine dry add-on.

Description of Test Conditions

Test samples one inch wide and six inches long in test direction were cut off each bonded web. Due to the limited size of bonded samples the number of test samples cut from each web were machine direction--five dry and five wet; cross-machine direction--three dry and three wet.

Dry tensile samples were conditioned overnight 72°F ± 2° and 65% relative humidity ± 2% before testing. Wet tensile samples were soaked for 20 minutes in water containing .10% nonionic surfactant to ensure uniform wet-out of material.

All tensiles were run on a Model X-3 Scott tester which had just been serviced and calibrated. Samples were tested according to ASTM-D1117 at a (CRT) constant rate of Traverse of 12.0 ± 0.5 inches/minute and a gauge length of 3.0 inches. Test results were recorded in pounds/inch.

Ratings of Results

Samples from each treated web were tested for both dry and wet tensile strength. Since there were no statistical differences (.05) between the duplicates of each set of fiber and binder, a representative sample of each set was dyed with an identification stain that dyed the fiber and binder a different color.[3]

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[2]Approximation using Arrhenius Energy of Activation Equation.

[3]T.I.S. Identification Stain #2, Test Fabrics, Inc.

Tensile strengths were examined by analysis of variance (significant at the .05 level) for differences as a function of the following variables:

1. the five binders
2. the replicates (duplicate sets)
3. the five binders and replicates

Results of the analysis of variance, significant at the .05 level, were tested by Scheffé's tests to determine where the differences lie.

The dyed samples were examined by microscope to assure that the binders were homogeneously distributed throughout the bonded webs (figures 7 and 8, appendix D). Additional data collected included thickness measurements of each treated web and measurements of the initial wet and dry pick-ups of various binder solutions by webs made of each fiber (chapter III, Application of Acrylic Latices; appendix C, table 13).

CHAPTER IV

ANALYSIS OF DATA AND DISCUSSION OF RESULTS

This chapter is a presentation of data collected on each experimental factor in the study. Each factor will be discussed, including data with tests for statistical significance. Machine direction will be referred to as MD and transverse (cross-machine) direction as TD.

Ratings of the Pick-Up Measurements of Various Solutions

The results of the various pick-up trials discussed in chapter III, Application of Acrylic Latices, were unexpected. All seven webs had the highest wet pick-up when padded with water only. The lowest wet pick-up, except for the rayon and PCP, was when the seven webs were padded with water and .20% nonionic surfactant. The most notable phenomena occurred when the webs were padded with water, nonionic surfactant and binder. The correlation between wet binder pick-up and dry solid add-on was not as expected. Rayon, with the highest wet pick-up, had next to the lowest dry add-on, while the PCP, MPE, and PE #2 with lower wet pick-up had approximately 50% higher add-on of solids (appendix C, table 13). Surface tension and pH of the various mixes are listed in table 4 along with the charges.

It should be noted that with the exception of the rayon webs the 5% dry add-on resulted in many samples having very low tensile measurements, specifically in the wet tests where several zero readings were

Table 4

Surface Tension and pH of Binder Mixes

	Charge		20% Solids Surface Tension Dynes/cm^2		5% Solids Surface Tension Dynes/cm^2	
Binder	Binder	Emulsifier		pH		pH
A	C	N	33.5	5.5	30.7	6.0
B	N	A	31.5	5.0	31.2	5.5
C	A	N	36.6	5.5	32.7	6.0
D	N	N	34.0	5.0	32.2	5.5
E	A	A	31.3	5.0	30.9	5.5

obtained. This was probably due to having inadequate binder add-on on the hydrophobic fibers.

The means of the measurement data were examined by analysis of variance for differences in tensile strength and found to differ significantly (.05 level) on the five binders (appendix A, table 7).

The analysis of variance looked separately at the MD and TD tensiles on each web with the five binders at each level of dry add-on for the dry and wet tests. This generated 56 sets of data of which 10 were not computed because no differences were present, specifically, zero standard deviations and some zero tensiles in the measurement data at 5% add-on.

Of the remaining 46 sets, 40 showed significant differences at .05 and even at .01 among the five binders. Since each factor was looked at separately, the same binder was not necessarily the strongest in both MD and TD for the same web at the same add-on. Also, the strength of the various binders was not the same when tested dry and wet.

All 40 were tested by Scheffé's tests to determine which binders differed significantly from each other at the .05 level (appendix B, table 8). On the basis of Scheffé's tests, it was possible to state which binders were the strongest with each fiber. These results were summarized and rank ordered in appendix B, table 9. It should be noted that since each of the ANOVAs was independent, each analysis of variance (ANOVA) had to be ranked separately. For example, on table 8 in appendix B, set number 30 at 20% add-on, dry test for PE # 1--TD sample, binder C, which had the highest tensile measurement, differs significantly (.05) from binders A, B, D, and E, was assigned a ranking of 1. Binder E, with the second highest tensile measurement and significantly different (.05) from binders A, B, and D, was assigned a ranking of 2. Binder A, with the lowest tensile and significantly different from binders B, C, D, and E, was assigned a ranking of 5. Each ANOVA was ranked in the same manner. In the event of ties, e.g., set number 2, dry test for PE # 1--MD test samples, binders C and E were each ranked 1.5 and binders A, B, and D were ranked 4.

On the basis of the ranked data, the strongest binder on each web was selected from each ANOVA and classified according to the four following variables (summarized in tables 5 and 6):

1. Binder charge vs. fiber charge.
2. Binder charge vs. fiber finish charge.

Table 5

Relationship of Highest Tensiles to Ionic Charges

20% Binder Add-On

Charges		Number of Highest Tensiles			
		Dry Test		Wet Test	
Binder	Fiber	MD	TD	MD	TD
C	N	1	1	0	0
C	A	1	1	0	1
C	C	0	0	0	0
N	N	1	3	1	0
N	A	0	1	0	0
N	C	0	0	1	0
A	N	4	6	3	3
A	A	2	1	1	2
A	C	0	1	2	0
Binder	Fiber Finish				
C	C	0	0	0	0
C	A	2	2	0	1
N	C	1	3	2	0
N	A	0	0	0	0
A	C	4	6	4	4
A	A	2	3	1	1
Binder Emulsifier	Fiber				
N	N	3	6	1	1
N	A	3	3	1	2
N	C	0	0	2	0
A	N	3	3	3	2
A	A	0	1	0	1
A	C	0	1	1	0
Binder Emulsifier	Fiber Finish				
N	C	2	5	4	1
N	A	4	4	0	2
A	C	3	4	3	3
A	A	0	1	1	0

Table 6

Relationship of Highest Tensile to Ionic Charges

5% Binder Add-On

Charges		Number of Highest Tensiles			
		Dry Test		Wet Test	
Binder	Fiber	MD	TD	MD	TD
C	N	0	0	0	0
C	A	0	0	0	0
C	C	0	0	0	0
N	N	2	1	5	2
N	A	1	1	1	1
N	C	0	0	2	0
A	N	4	2	3	0
A	A	0	1	0	0
A	C	1	0	2	0
Binder	Fiber Finish				
C	C	0	0	0	0
C	A	0	0	0	0
N	C	3	2	7	3
N	A	0	0	1	0
A	C	4	3	4	0
A	A	1	0	1	0
Binder Emulsifier	Fiber				
N	N	2	1	2	0
N	A	0	0	0	0
N	C	1	0	2	0
A	N	4	2	6	2
A	A	1	2	1	1
A	C	0	0	2	0
Binder Emulsifier	Fiber Finish				
N	C	3	1	4	0
N	A	0	0	0	0
A	C	4	4	7	3
A	A	1	0	2	0

3. Binder emulsifier charge vs. fiber charge.

4. Binder emulsifier charge vs. fiber finish charge.

The following is an evaluation of the four above variables:

1. Binder charge vs. fiber charge. The highest number of strong bonds are seen when the binder charge is anionic and the fiber charge is nonionic at both levels of add-on, dry and wet tests and both MD and TD samples.

2. Binder charge vs. fiber finish charge. The highest number of strong bonds is seen when the binder charge is anionic and the fiber finish charge is cationic. This holds for 20% add-on both dry and wet and both MD and TD tests. It also holds up at 5% add-on for the dry tests on both MD and TD but not for the wet tests.

3. Binder emulsifier vs. fiber charge. At 20% add-on MD dry tests, there are three ties for the highest number of strong bonds among the following: (a) nonionic emulsifier/nonionic fiber, (b) nonionic emulsifier/anionic fiber, and (c) anionic emulsifier/nonionic fiber. At 20% TD dry test, the highest number of strong bonds was present where both emulsifier and fiber had nonionic charges. At 5% add-on, both MD and TD dry and wet tests showed the highest number of strong bonds where the emulsifier was anionic and the fiber was nonionic.

4. Binder emulsifier vs. fiber finish. At 20% add-on, the results on both MD and TD dry tests were about equal, except

when anionic charges were on both emulsifier and fiber finish. At 20% add-on, MD wet test, the highest number of strong bonds was present when the charge on the emulsifier was nonionic and cationic on the fiber finish. At 5% add-on, the highest number of strong bonds was noted for both MD and TD dry and wet tests when binder emulsifier was anionic and fiber finish cationic.

Overall Rating and Evaluations

While no one binder yielded the highest tensiles on every fiber, the two binders (A and E) with anionic charged polymers had higher tensiles overall than any of the others. The two anionic binders also have the highest Tg which means they will form the stiffest films. However, with some fibers, the two softest binders (A and B) did have some high values equal to the others. The best result for binder D, with nonionic charges on both polymer and emulsifier, was a four-way tie on rayon at 20% add-on on the TD dry test.

The results of the data from the analysis of variance showed significant differences (.05) among the five binders. Scheffé's tests showed which binders differed significantly (.05) from each and also, which were the strongest on each web.

The conclusions made here are made in relation to the hypotheses of chapter I based on ranking Scheffé's tests.

H_1: There are no differences in tensile strength among nonwovens bonded with the five binders at equal add-on on each of the seven webs as a function of the ionic charge on the binder and on the web. This hypothesis was accepted.

H_2: There are no differences in tensile strength among nonwovens bonded with the five binders at equal add-on on each of the seven webs as a function of the ionic charge on the binder and the fiber finish. This hypothesis was rejected.

H_3: There are no differences in tensile strength among nonwovens bonded with the five binders at equal add-on on each of the seven webs as a function of the ionic charge on the binder emulsifier and the fiber. This hypothesis was accepted.

H_4: There are no differences in tensile strength among nonwovens bonded with the five binders at equal add-on on each of the seven webs as a function of the ionic charge on the binder emulsifier and fiber finish. This hypothesis was rejected.

CHAPTER V

SUMMARY AND CONCLUSIONS

In this study, individual webs were carded from seven chemically different fibers--one rayon control, two polyester, one modified polyester, one polyester copolymer, and two polypropylenes. The webs were padded with five chemically different acrylic binders at 5% and 20% dry add-on. The treated webs were air dried, oven cured, conditioned, and then tested to determine thickness and both dry and wet tensiles. The selected fibers and binders had varying ionic charges on the binder polymer and its emulsifier, and on the fiber and its finish. Due to differences in weight among the seven webs, the tensile data were normalized to a standard fabric weight of 1.0 ounce per square yard (oz/yd^2).

The following conclusions are based on the ranking of Scheffé's tests (.05):

1. Significant differences in tensile strength were found among the five binders on the seven fabrics.
2. There was no indication of ionic interaction to yield greater tensile strength as a function of charges on the binder and on the fiber.
3. Ionic interaction between the binder and the fiber finish appeared to yield greater tensile strength on the fabrics.

4. There was no indication of ionic interaction to yield greater tensile strength as a function of charges on the binder emulsifier and on the fiber.
5. Ionic interaction between the binder emulsifier and the fiber finish appeared to yield greater tensile strength on the fabrics; this suggests that ionic charge interaction may be responsible for better wetting of the fiber by the binder.
6. There was no indication that the surface tensions of the binders in this study had any bearing on the tensile strength of the fabrics.
7. Unrelated to ionic charges, the tensile strength is positively related to binder stiffness.

The above conclusions are consistent with the knowledge that ionic charges buried in polymer backbones such as fibers and binders should not interact because of excessive separation between charges and immobility. However, when charges are present in small molecules and on the surface as in fiber finishes and binder emulsifiers, interactions should be expected and were found.

Recommendations

Future research should be carried out using a factorial design to give further insight into the role of ionic charges in the resulting tensile strength of chemically bonded nonwoven fabrics. The statistical predictions of the study should be validated by actual preparation of nonwoven fabrics. A study of bonded webs by means of a scanning electron microscope could provide valuable information in regard to the bonding in these systems.

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APPENDIX A

ANALYSIS OF VARIANCE

Table 7

Analysis of Variance

ANOVA	df	SS	MS	F	
Set #1 Composed of MD - Dry Samples A1-E2					
Binder	4	6032842.183	1508210.546	22.058*	F4,40
Rep	1	8180.744	8180.744	**	F1,40
Binder & Rep	4	90270.563	22567.641	**	F4,40
Error	40	2734967.000	68374.175		
Total	49				
Set #2 Composed of MD - Dry Samples A3-E4					
Binder	4	625901.322	156475.330	7.340*	F4,40
Rep	1	2541.474	2541.474	**	F1,40
Binder & Rep	4	24563.623	6140.906	**	F4,40
Error	40	852680.300	21317.008		
Total	49				
Set #3 Composed of MD - Dry Samples A5-E6					
Binder	4	181010.269	45252.565	4.165*	F4,40
Rep	1	2625.696	2625.696	**	F1,40
Binder & Rep	4	4157.348	1039.337	**	F4,40
Error	40	434576.200	10864.405		
Total	49				
Set #4 Composed of MD - Dry Samples A7-E8					
Binder	4	26960.622	6740.155	1.317**	F4,40
Rep	1	2867.604	2867.604	**	F1,40
Binder & Rep	4	4840.017	1210.004	**	F4,40
Error	40	204640.000	5116.000		
Total	49				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #5 Composed of MD - Dry Samples A9-E10					
Binder	4	1044954.530	261238.630	5.867*	F4,40
Rep	1	3135.024	3135.024	**	F1,40
Binder & Rep	4	14992.878	3748.219	**	F4,40
Error	40	1781001.000	44525.025		
Total	49				
Set #6 Composed of MD - Dry Samples A11-E12					
Binder	4	862789.576	215697.390	4.531*	F4,40
Rep	1	8.427	8.427	**	F1,40
Binder & Rep	4	4469.743	1117.436	**	F4,40
Error	40	1904388.000	47609.700		
Total	49				
Set #7 Composed of MD - Dry Samples A13-E14					
Binder	4	308009.293	77002.323	37.462*	F4,40
Rep	1	296.916	296.916	**	F1,40
Binder & Rep	4	880.081	220.020	**	F4,40
Error	40	82218.530	2055.463		
Total	49				
Set #8 Composed of MD - Dry Samples A21-E22					
Binder	4	162415.294	40603.823	1.859**	F4,40
Rep	1	457.652	457.652	**	F1,40
Binder & Rep	4	7057.420	1764.355	**	F4,40
Error	40	873795.200	21844.880		
Total	49				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #9 Composed of MD - Dry Samples A23-E24					
Binder	4	7921.274	1980.319	3.924*	F4,40
Rep	1	19.768	19.768	**	F1,40
Binder & Rep	4	198.923	49.731	**	F4,40
Error	40	20186.200	504.655		
Total	49				
Set #10 Composed of MD - Dry Samples A25-E26					
Binder	4	12676.116	3169.028	8.696*	F4,40
Rep	1	1.136	1.136	**	F1,40
Binder & Rep	4	13.490	3.373	**	F4,40
Error	40	14576.870	364.422		
Total	49				
Set #11 Composed of MD - Dry Samples A27-E28					
Binder	4	5313.933	1328.483	8.508*	F4,40
Rep	1	17.344	17.344	**	F1,40
Binder & Rep	4	33.430	8.358	**	F4,40
Error	40	6245.886	156.147		
Total	49				
Set #12 Composed of MD - Dry Samples A29-E30					
Binder	4	110461.867	27615.465	7.139*	F4,40
Rep	1	1277.804	1277.804	**	F1,40
Binder & Rep	4	2172.112	543.028	**	F4,40
Error	40	154726.900	3868.173		
Total	49				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #13 Composed of MD - Dry Samples A31-E32					
Binder	4	60816.087	15204.022	8.944*	F4,40
Rep	1	4.624	4.624	**	F1,40
Binder & Rep	4	724.383	181.096	**	F4,40
Error	40	68004.280	1700.107		
Total	49				
Set #14 Composed of MD - Dry Samples A33-E34					
Binder	4	2609.665	652.416	1.208**	F4,40
Rep	1	119.094	119.094	**	F1,40
Binder & Rep	4	267.207	66.802	**	F4,40
Error	40	21610.260	540.257		
Total	49				
Set #15 Composed of MD - Wet Samples A1-E2					
Binder	4	876289.807	219072.450	105.276*	F4,40
Rep	1	7174.898	7174.898	3.448**	F1,40
Binder & Rep	4	84845.590	21211.398	10.193*	F4,40
Error	40	832371.200	2080.928		
Total	49				
Set #16 Composed of MD - Wet Samples A3-E4					
Binder	4	181839.803	45459.950	4.596*	F4,40
Rep	1	6.691	6.691	**	F1,40
Binder & Rep	4	2719.453	679.856	**	F4,40
Error	40	395655.900	9891.398		
Total	49				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #17 Composed of MD - Wet Samples A5-E6					
Binder	4	45091.439	11272.860	9.238*	F4,40
Rep	1	1529.427	1529.427	1.253**	F1,40
Binder & Rep	4	966.866	241.716	**	F4,40
Error	40	48808.480	1220.212		
Total	49				
Set #18 Composed of MD - Wet Samples A7-E8					
Binder	4	24410.516	6102.629	9.335*	F4,40
Rep	1	145.390	145.390	**	F1,40
Binder & Rep	4	750.594	187.648	**	F4,40
Error	40	26148.610	653.715		
Total	49				
Set #19 Composed of MD - Wet Samples A9-E10					
Binder	4	114416.248	28604.063	8.170*	F4,40
Rep	1	125.387	125.387	**	F1,40
Binder & Rep	4	4170.503	1042.626	**	F4,40
Error	40	140040.100	3501.003		
Total	49				
Set #20 Composed of MD - Wet Samples A11-E12					
Binder	4	144174.318	36043.578	4.470*	F4,40
Rep	1	463.761	463.761	**	F1,40
Binder & Rep	4	3657.253	914.313	**	F4,40
Error	40	322508.400	8062.710		
Total	49				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #21 Composed of MD - Wet Samples A13-E14					
Binder	4	26964.052	6741.013	2.464**	F4,40
Rep	1	49.551	49.551	**	F1,40
Binder & Rep	4	368.673	92.168	**	F4,40
Error	40	109426.300	2735.658		
Total	49				
Set #22 Composed of MD - Wet Samples A21-E22					
Binder	4	175269.645	43817.410	8.654*	F4,40
Rep	1	138.607	138.607	**	F1,40
Binder & Rep	4	10979.813	2744.953	**	F4,40
Error	40	202537.000	5063.425		
Total	49				
Set #23 Composed of MD - Wet Samples A23-E24					
Binder	4	6799.592	1699.898	16.951*	F4,50
Rep	1	36.366	36.366	**	F1,40
Binder & Rep	4	48.344	12.086	**	F4,40
Error	40	4011.380	100.285		
Total	49				
Set #24 Composed of MD - Wet Samples A25-E26					
Binder	4	8345.202	2086.301	13.914*	F4,40
Rep	1	10.000	10.000	**	F1,40
Binder & Rep	4	184.930	46.232	**	F4,40
Error	40	5997.621	149.941		
Total	49				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #25 Composed of MD - Wet Samples A27-E28					
Binder	4	2111.409	527.852	8.861*	F4,40
Rep	1	0	0	**	F1,40
Binder & Rep	4	1.445	.361	**	F4,40
Error	40	2382.716	59.568		
Total	49				
Set #26 Composed of MD - Wet Samples A29-E30					
Binder	4	37336.604	9334.151	7.407*	F4,40
Rep	1	4788.219	4788.219	3.799**	F1,40
Binder & Rep	4	5265.403	1316.351	1.045*	F4,40
Error	40	50406.500	1260.163		
Total	49				
Set #27 Composed of MD - Wet Samples A31-E32					
Binder	4	8658.411	2164.603	4.618*	F4,40
Rep	1	227.338	227.338	**	F1,40
Binder & Rep	4	1148.622	287.155	**	F4,40
Error	40	18749.220	468.731		
Total	49				
Set #28 Composed of MD - Wet Samples A33-E34					
Binder	4	412.664	103.166	1.184**	F4,40
Rep	1	1.665	1.665	**	F1,40
Binder & Rep	4	20.664	5.659	**	F4,40
Error	40	3485.878	87.147		
Total	49				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #29 Composed of TD - Dry Samples A1-E2					
Binder	4	2246470.651	561617.680	13.836*	F4,20
Rep	1	100.997	100.997	**	F1,20
Binder & Rep	4	31754.231	7938.558	**	F4,20
Error	20	811824.500	40591.225		
Total	29				
Set #30 Composed of TD - Dry Samples A3-E4					
Binder	4	134816.378	33704.093	45.691*	F4,20
Rep	1	588.749	588.749	**	F1,20
Binder & Rep	4	1818.869	454.717	**	F4,20
Error	20	14752.920	737.646		
Total	29				
Set #31 Composed of TD - Dry Samples A5-E6					
Binder	4	6466.154	1616.539	20.379*	F4,20
Rep	1	9.101	9.101	**	F1,20
Binder & Rep	4	107.658	26.915	**	F4,20
Error	20	1586.495	79.325		
Total	29				
Set #32 Composed of TD - Dry Samples A7-E8					
Binder	4	2034.778	508.695	12.963*	F4,20
Rep	1	.188	.188	**	F1,20
Binder & Rep	4	70.236	17.559	**	F4,20
Error	20	784.790	39.239		
Total	29				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #33 Composed of TD - Dry Samples A9-E10					
Binder	4	162415.294	40603.823	40.579*	F4,20
Rep	1	457.652	457.652	**	F1,20
Binder & Rep	4	7057.420	1764.355	1.763**	F4,20
Error	20	20012.295	1000.615		
Total	29				
Set #34 Composed of TD - Dry Samples A11-E12					
Binder	4	306554.473	76638.518	60.751*	F4,20
Rep	1	1080.976	1080.976	**	F1,20
Binder & Rep	4	5127.257	1281.814	1.016**	F4,20
Error	20	25230.500	1261.525		
Total	29				
Set #35 Composed of TD - Dry Samples A13-E14					
Binder	4	231983.185	57995.795	164.423*	F4,20
Rep	1	.185	.185	**	F1,20
Binder & Rep	4	215.119	.610	**	F4,20
Error	20	7054.475	352.724		
Total	29				
Set #36 Composed of TD - Dry Samples A21-E22					
Binder	4	128230.360	32057.588	12.911*	F4,20
Rep	1	3330.990	3330.990	1.342**	F1,20
Binder & Rep	4	3086.418	771.605	**	F4,20
Error	20	49659.950	2482.998		
Total	29				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #37 Composed of TD - Dry Samples A23-E24 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				
Set #38 Composed of TD - Dry Samples A25-E26 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				
Set #39 Composed of TD - Dry Samples A27-E28 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				
Set #40 Composed of TD - Dry Samples A29-E30 - No Differences					
Binder	4	29355.825	7333.956	10.469*	F4,20
Rep	1	47.480	47.480	**	F1,20
Binder & Rep	4	1630.611	407.653	**	F4,20
Error	20	14011.415	700.571		
Total	29				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #41 Composed of TD - Dry Samples A31-E32					
Binder	4	1452.229	363.057	1.442**	F4,20
Rep	1	4.020	4.020	**	F1,20
Binder & Rep	4	1303.461	325.865	1.294**	F4,20
Error	20	5036.000	251.800		
Total	29				
Set #42 Composed of TS - Dry Samples A33-E34 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				
Set #43 Composed of TD - Wet Samples A1-E2					
Binder	4	339794.593	84948.648	76.297*	F4,20
Rep	1	10983.922	10983.922	9.865*	F1,20
Binder & Rep	4	14543.545	3635.886	3.266*	F4,20
Error	20	22267.990	1113.400		
Total	29				
Set #44 Composed of TD - Wet Samples A3-E4					
Binder	4	17825.388	4456.347	12.083*	F4,20
Rep	1	109.760	109.760	**	F1,20
Binder & Rep	4	884.277	221.069	**	F4,20
Error	20	7376.525	368.826		
Total	29				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #45 Composed of TD - Wet Samples A5-E6 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				
Set #46 Composed of TD - Wet Samples A7-E8 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				
Set #47 Composed of TD - Wet Samples A9-E10					
Binder	4	58767.941	14691.985	75.441*	F4,20
Rep	1	2.070	2.070	**	F1,20
Binder & Rep	4	236.335	59.084	**	F4,20
Error	20	3894.955	194.748		
Total	29				
Set #48 Composed of TD - Wet Samples A11-E12					
Binder	4	116248.515	29062.128	110.137*	F4,20
Rep	1	40.000	40.000	**	F1,20
Binder & Rep	4	415.705	103.926	**	F4,20
Error	20	5277.435	263.872		
Total	29				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #49 Composed of TD - Wet Samples A13-E14					
Binder	4	37230.919	9307.730	8.241*	F4,20
Rep	1	26.732	26.732	**	F1,20
Binder & Rep	4	67.271	16.818	**	F4,20
Error	20	22587.165	1129.358		
Total	29				
Set #50 Composed of TD - Wet Samples A21-E22					
Binder	4	44804.033	11201.008	12.823*	F4,20
Rep	1	720.631	720.631	**	F1,20
Binder & Rep	4	2792.891	698.223	**	F4,20
Error	20	17469.875	873.494		
Total	29				
Set #51 Composed of TD - Wet Samples A23-E24 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				
Set #52 Composed of TD - Wet Samples A25-E26 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				

Table 7 - Continued

ANOVA	df	SS	MS	F	
Set #53 Composed of TD - Wet Samples A27-E28 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				
Set #54 Composed of TD - Wet Samples A29-E30					
Binder	4	6691.341	1672.835	8.536*	F4,20
Rep	1	15.080	15.080	**	F1,20
Binder & Rep	4	1121.494,	280.374	1.431**	F4,20
Error	20	3919.412	195.971		
Total	29				
Set #55 Composed of TD - Wet Samples A31-E32					
Binder	4	3987.756	996.939	6.977*	F4,20
Rep	1	272.588	272.588	1.908**	F1,20
Binder & Rep	4	578.743	144.686	1.013**	F4,20
Error	20	2857.844	142.892		
Total	29				
Set #56 Composed of TD - Wet Samples A33-E34 - No Differences					
Binder	4				
Rep	1				
Binder & Rep	4				
Error	20				
Total	29				

*Significant at .05

**Not significant at .05

APPENDIX B

SCHEFFÉ'S TESTS OF ANALYSIS OF VARIANCE

SUMMARY OF SCHEFFÉ'S TESTS ON ANOVAS

TABLE 8

SCHEFFÉ'S TESTS OF ANALYSIS OF VARIANCE DATA

SET NUMBER 1 SAMPLES:MD-DRY A1-E2	SET NUMBER 2 SAMPLES:MD-DRY A3-E4
CRITICAL DIFFERENCE 377.84	CRITICAL DIFFERENCE 210.97
A= 148.50 B= 2796.64 C= 3125.79 D= 3059.96 E= 3473.10	A= 392.55 B= 528.91 C= 1019.23 D= 478.97 E= 910.27
A-B=-2648.14 A-C=-2977.29 A-D=-2911.46 A-E=-3324.60 B-C= -329.15 B-D= -263.32 B-E= -676.46 C-D= 65.83 C-E= -347.31 D-E= -413.14	A-B= -136.36 A-C= -626.68 A-D= -86.42 A-E= -517.72 B-C= -490.32 B-D= 49.94 B-E= -381.36 C-D= 540.26 C-E= 108.96 D-E= -431.30

SET NUMBER 3 SAMPLES:MD-DRY A5-E6	SET NUMBER 4 SAMPLES:MD-DRY A7-E8
CRITICAL DIFFERENCE 150.61	CRITICAL DIFFERENCE 0
A= 692.35 B= 357.30 C= 708.24 D= 466.94 E= 597.01	A= 522.10 B= 519.83 C= 467.70 D= 425.17 E= 581.12
A-B= 335.05 A-C= -15.89 A-D= 225.41 A-E= 95.34 B-C= -350.94 B-D= -109.64 B-E= -239.71 C-D= 241.30 C-E= 111.23 D-E= -130.07	A-B= 0.00 A-C= 0.00 A-D= 0.00 A-E= 0.00 B-C= 0.00 B-D= 0.00 B-E= 0.00 C-D= 0.00 C-E= 0.00 D-E= 0.00

TABLE 8-Continued

SET NUMBER 5 SAMPLES:MD-DRY A9-E10	SET NUMBER 6 SAMPLES:MD-DRY A11-E12
CRITICAL DIFFERENCE 304.90	CRITICAL DIFFERENCE 315.29
A= 1162.24	A= 921.62
B= 1432.37	B= 1432.37
C= 1713.85	C= 1364.27
D= 760.45	D= 631.06
E= 1080.52	E= 1089.65
A-B= -270.13	A-B= -510.75
A-C= -551.61	A-C= -442.65
A-D= 401.79	A-D= 290.56
A-E= 81.72	A-E= -168.03
B-C= -281.48	B-C= 68.10
B-D= 671.92	B-D= 801.31
B-E= 351.85	B-E= 342.72
C-D= 953.40	C-D= 733.21
C-E= 633.33	C-E= 274.62
D-E= -320.07	D-E= -458.59

SET NUMBER 7 SAMPLES:MD-DRY A13-E14	SET NUMBER 8 SAMPLES:A21-E22
CRITICAL DIFFERENCE 65.51	CRITICAL DIFFERENCE 0
A= 658.30	A= 449.92
B= 268.99	B= 994.26
C= 651.49	C= 1327.95
D= 256.28	D= 1223.53
E= 465.35	E= 1452.80
A-B= 389.31	A-B= 0.00
A-C= 6.81	A-C= 0.00
A-D= 402.02	A-D= 0.00
A-E= 192.95	A-E= 0.00
B-C= -382.50	B-C= 0.00
B-D= 12.71	B-D= 0.00
B-E= -196.36	B-E= 0.00
C-D= 395.21	C-D= 0.00
C-E= 186.14	C-E= 0.00
D-E= -209.07	D-E= 0.00

TABLE 8-Continued

SET NUMBER 9 SAMPLES:MD-DRY A23-E24		SET NUMBER 10 SAMPLES:MD-DRY A25-E26	
CRITICAL DIFFERENCE 32.46		CRITICAL DIFFERENCE 27.58	
A=	0.00	A=	0.00
B=	79.45	B=	49.72
C=	69.69	C=	74.91
D=	64.24	D=	46.99
E=	61.06	E=	108.28
A-B=	-79.45	A-B=	-49.72
A-C=	-69.69	A-C=	-74.91
A-D=	-64.24	A-D=	-46.99
A-E=	-61.06	A-E=	-108.28
B-C=	9.76	B-C=	-25.19
B-D=	15.21	B-D=	2.73
B-E=	18.39	B-E=	-58.56
C-D=	5.45	C-D=	27.92
C-E=	8.63	C-E=	-33.37
D-E=	3.18	D-E=	-61.29

SET NUMBER 11 SAMPLES:MD-DRY A27-E28		SET NUMBER 12 SAMPLES:MD-DRY A29-E30	
CRITICAL DIFFERENCE 18.07		CRITICAL DIFFERENCE 89.87	
A=	0.00	A=	218.15
B=	43.13	B=	508.48
C=	69.92	C=	240.62
D=	41.54	D=	361.15
E=	52.66	E=	283.06
A-B=	-43.13	A-B=	-290.33
A-C=	-69.92	A-C=	-22.47
A-D=	-41.54	A-D=	-143.00
A-E=	-52.66	A-E=	-64.91
B-C=	-26.79	B-C=	267.86
B-D=	1.59	B-D=	147.33
B-E=	-9.53	B-E=	225.42
C-D=	28.38	C-D=	-120.53
C-E=	17.26	C-E=	-42.44
D-E=	-11.12	D-E=	78.09

TABLE 8-Continued

SET NUMBER 13 SAMPLES:MD-DRY A31-E32	SET NUMBER 14 SAMPLES:MD-DRY A33-E34
CRITICAL DIFFERENCE 59.58	CRITICAL DIFFERENCE 0
A= 217.92	A= 45.17
B= 274.89	B= 83.09
C= 214.06	C= 66.06
D= 135.74	D= 91.49
E= 371.14	E= 79.22
A-B= -56.97	A-B= 0.00
A-C= 3.86	A-C= 0.00
A-D= 82.18	A-D= 0.00
A-E= -153.22	A-E= 0.00
B-C= 60.83	B-C= 0.00
B-D= 139.15	B-D= 0.00
B-E= -96.25	B-E= 0.00
C-D= 78.32	C-D= 0.00
C-E= -157.08	C-E= 0.00
D-E= -235.40	D-E= 0.00

SET NUMBER 15 SAMPLES:MD-WET A1-E2	SET NUMBER 16 SAMPLES:MD-WET A3-E4
CRITICAL DIFFERENCE 65.91	CRITICAL DIFFERENCE 143.71
A= 681.00	A= 242.89
B= 1480.04	B= 221.55
C= 1407.04	C= 251.74
D= 1348.38	D= 212.70
E= 1418.75	E= 567.50
A-B= -799.04	A-B= 21.34
A-C= -726.04	A-C= -8.85
A-D= -667.38	A-D= 30.19
A-E= -737.75	A-E= -324.61
B-C= 73.00	B-C= -30.19
B-D= 131.66	B-D= 8.85
B-E= 61.29	B-E= -345.95
C-D= 58.66	C-D= 39.04
C-E= -11.71	C-E= -315.76
D-E= -70.37	D-E= -354.80

TABLE 8-Continued

SET NUMBER 17 SAMPLES:MD-WET A5-E6	SET NUMBER 18 SAMPLES:MD-WET A7-E8
CRITICAL DIFFERENCE 50.47	CRITICAL DIFFERENCE 36.94
A= 90.80	A= 85.80
B= 212.24	B= 160.71
C= 153.68	C= 240.07
D= 225.41	D= 204.75
E= 288.60	E= 223.14
A-B= -121.44	A-B= -74.91
A-C= -62.88	A-C= -154.27
A-D= -134.61	A-D= -118.95
A-E= -197.80	A-E= -137.34
B-C= 58.56	B-C= -79.36
B-D= -13.17	B-D= -44.04
B-E= -76.36	B-E= -62.43
C-D= -71.73	C-D= 35.32
C-E= -134.92	C-E= 16.93
D-E= -63.19	D-E= -18.39

SET NUMBER 19 SAMPLES:MD-WET A9-E10	SET NUMBER 20 SAMPLES:MD-WET A11-E12
CRITICAL DIFFERENCE 85.49	CRITICAL DIFFERENCE 129.74
A= 599.28	A= 513.02
B= 526.64	B= 419.04
C= 612.90	C= 687.81
D= 314.16	D= 325.51
E= 522.10	E= 508.48
A-B= 72.64	A-B= 93.98
A-C= -13.62	A-C= -174.79
A-D= 285.12	A-D= 187.51
A-E= 77.18	A-E= 4.54
B-C= -86.26	B-C= -268.77
B-D= 212.48	B-D= 93.53
B-E= 4.54	B-E= -89.44
C-D= 298.74	C-D= 362.30
C-E= 90.80	C-E= 179.33
D-E= -207.94	D-E= -182.97

TABLE 8-Continued

SET NUMBER 21 SAMPLES:MD-WET A13-E14		SET NUMBER 22 SAMPLES:MD-WET A21-E22	
CRITICAL DIFFERENCE 0		CRITICAL DIFFERENCE 102.82	
A=	277.62	A=	311.89
B=	184.10	B=	705.97
C=	244.03	C=	594.74
D=	146.19	D=	553.88
E=	274.67	E=	619.71
A-B=	0.00	A-B=	-394.08
A-C=	0.00	A-C=	-282.85
A-D=	0.00	A-D=	-241.99
A-E=	0.00	A-E=	-307.82
B-C=	0.00	B-C=	111.23
B-D=	0.00	B-D=	152.09
B-E=	0.00	B-E=	86.26
C-D=	0.00	C-D=	40.86
C-E=	0.00	C-E=	-24.97
D-E=	0.00	D-E=	-65.83

SET NUMBER 23 SAMPLES:MD-WET A23-E24		SET NUMBER 24 SAMPLES:MD-WET A25-E26	
CRITICAL DIFFERENCE 14.47		CRITICAL DIFFERENCE 17.69	
A=	0.00	A=	0.00
B=	68.33	B=	71.73
C=	58.56	C=	48.12
D=	58.57	D=	51.07
E=	70.60	E=	84.67
A-B=	-68.33	A-B=	-71.73
A-C=	-58.56	A-C=	-48.12
A-D=	-58.57	A-D=	-51.07
A-E=	-70.60	A-E=	-84.67
B-C=	9.77	B-C=	23.61
B-D=	9.76	B-D=	20.66
B-E=	-2.27	B-E=	-12.94
C-D=	-0.01	C-D=	-2.95
C-E=	-12.04	C-E=	-36.55
D-E=	-12.03	D-E=	-33.60

TABLE 8-Continued

SET NUMBER 25 SAMPLES:MD-WET A27-E28	SET NUMBER 26 SAMPLES:MD-WET A29-E30
CRITICAL DIFFERENCE 11.15	CRITICAL DIFFERENCE 51.29
A= 0.00	A= 171.61
B= 39.27	B= 324.38
C= 39.27	C= 156.18
D= 28.14	D= 241.98
E= 32.23	E= 189.54
A-B= -39.27	A-B= -152.77
A-C= -39.27	A-C= 15.43
A-D= -28.14	A-D= -70.37
A-E= -32.23	A-E= -17.93
B-C= 0.00	B-C= 168.20
B-D= 11.13	B-D= 82.40
B-E= 7.04	B-E= 134.84
C-D= 11.13	C-D= -85.80
C-E= 7.04	C-E= -33.36
D-E= -4.09	D-E= 52.44

SET NUMBER 27 SAMPLES:MD-WET A31-E32	SET NUMBER 28 SAMPLES:MD-WET A33-E34
CRITICAL DIFFERENCE 31.28	CRITICAL DIFFERENCE 0
A= 139.83	A= 82.63
B= 150.73	B= 83.31
C= 113.04	C= 88.08
D= 68.55	D= 71.28
E= 137.79	E= 73.10
A-B= -10.90	A-B= 0.00
A-C= 26.79	A-C= 0.00
A-D= 71.28	A-D= 0.00
A-E= 2.04	A-E= 0.00
B-C= 37.69	B-C= 0.00
B-D= 82.18	B-D= 0.00
B-E= 12.94	B-E= 0.00
C-D= 44.49	C-D= 0.00
C-E= -24.75	C-E= 0.00
D-E= -69.24	D-E= 0.00

TABLE 8-Continued

SET NUMBER 29 SAMPLES:TD-DRY A1-E2	SET NUMBER 30 SAMPLES:TD-DRY A3-E4
CRITICAL DIFFERENCE 394.11	CRITICAL DIFFERENCE 53.12
A= 577.96	A= 249.01
B= 1593.54	B= 335.96
C= 1845.51	C= 578.95
D= 1464.15	D= 392.71
E= 1850.05	E= 494.86
A-B=-1015.58	A-B= -86.95
A-C=-1267.55	A-C= -329.94
A-D= -886.19	A-D= -143.70
A-E=-1272.09	A-E= -245.85
B-C= -251.97	B-C= -242.99
B-D= 129.39	B-D= -56.75
B-E= -256.51	B-E= -158.90
C-D= 381.36	C-D= 186.24
C-E= -4.54	C-E= 84.09
D-E= -385.90	D-E= -102.15

SET NUMBER 31 SAMPLES:TD-DRY A5-E6	SET NUMBER 32 SAMPLES:TD-DRY A7-E8
CRITICAL DIFFERENCE 17.42	CRITICAL DIFFERENCE 12.25
A= 105.78	A= 50.49
B= 45.85	B= 84.67
C= 113.04	C= 80.58
D= 71.28	D= 80.36
E= 103.28	E= 94.88
A-B= 59.93	A-B= -34.18
A-C= -7.26	A-C= -30.09
A-D= 34.50	A-D= -29.87
A-E= 2.50	A-E= -44.39
B-C= -67.19	B-C= 4.09
B-D= -25.43	B-D= 4.31
B-E= -57.43	B-E= -10.21
C-D= 41.76	C-D= 0.22
C-E= 9.76	C-E= -14.30
D-E= -32.00	D-E= -14.52

TABLE 8-Continued

SET NUMBER 33 SAMPLES:TD-DRY A9-E10	SET NUMBER 34 SAMPLES:TD-DRY A11-E12
CRITICAL DIFFERENCE 61.87	CRITICAL DIFFERENCE 69.47
A= 649.22	A= 642.41
B= 799.04	B= 433.34
C= 740.02	C= 783.15
D= 428.80	D= 273.31
E= 603.82	E= 574.31
A-B= -149.82	A-B= 209.07
A-C= -90.80	A-C= -140.74
A-D= 220.42	A-D= 369.10
A-E= 45.40	A-E= 68.10
B-C= 59.02	B-C= -349.81
B-D= 370.24	B-D= 160.03
B-E= 195.22	B-E= -140.97
C-D= 311.22	C-D= 509.84
C-E= 136.20	C-E= 208.84
D-E= -175.02	D-E= -301.00

SET NUMBER 35 SAMPLES:TD-DRY A13-E14	SET NUMBER 36 SAMPLES:TD-DRY A21-E22
CRITICAL DIFFERENCE 36.73	CRITICAL DIFFERENCE 97.47
A= 499.40	A= 246.29
B= 196.81	B= 510.75
C= 517.56	C= 558.42
D= 159.35	D= 372.05
E= 256.96	E= 494.86
A-B= 302.59	A-B= -264.46
A-C= -18.16	A-C= -312.13
A-D= 340.05	A-D= -125.76
A-E= 242.44	A-E= -248.57
B-C= -320.75	B-C= -47.67
B-D= 37.46	B-D= 138.70
B-E= -60.15	B-E= 15.89
C-D= 358.21	C-D= 186.37
C-E= 260.60	C-E= 63.56
D-E= -97.61	D-E= -122.81

TABLE 8-Continued

SET NUMBER 37 SAMPLES:TD-DRY A23-E24		SET NUMBER 38 SAMPLES:TD-DRY A25-E26	
CRITICAL DIFFERENCE 0		CRITICAL DIFFERENCE 0	
A=	0.00	A=	0.00
B=	32.69	B=	0.00
C=	44.95	C=	0.00
D=	50.39	D=	0.00
E=	46.99	E=	0.00
A-B=	0.00	A-B=	0.00
A-C=	0.00	A-C=	0.00
A-D=	0.00	A-D=	0.00
A-E=	0.00	A-E=	0.00
B-C=	0.00	B-C=	0.00
B-D=	0.00	B-D=	0.00
B-E=	0.00	B-E=	0.00
C-D=	0.00	C-D=	0.00
C-E=	0.00	C-E=	0.00
D-E=	0.00	D-E=	0.00

SET NUMBER 39 SAMPLES:TD-DRY A27-E28		SET NUMBER 40 SAMPLES:TD-DRY A29-E30	
CRITICAL DIFFERENCE 0		CRITICAL DIFFERENCE 51.77	
A=	0.00	A=	108.27
B=	0.00	B=	241.53
C=	0.00	C=	112.13
D=	0.00	D=	163.89
E=	0.00	E=	218.60
A-B=	0.00	A-B=	-133.26
A-C=	0.00	A-C=	-3.86
A-D=	0.00	A-D=	-55.62
A-E=	0.00	A-E=	-110.33
B-C=	0.00	B-C=	129.40
B-D=	0.00	B-D=	77.64
B-E=	0.00	B-E=	22.93
C-D=	0.00	C-D=	-51.76
C-E=	0.00	C-E=	-106.47
D-E=	0.00	D-E=	-54.71

TABLE 8-Continued

SET NUMBER 41 SAMPLES:TD-DRY A31-E32		SET NUMBER 42 SAMPLES:TD-DRY A33-E34	
CRITICAL DIFFERENCE 0		CRITICAL DIFFERENCE 0	
A=	137.11	A=	19.98
B=	170.25	B=	76.96
C=	157.54	C=	43.81
D=	157.09	D=	39.73
E=	169.80	E=	39.50
A-B=	0.00	A-B=	0.00
A-C=	0.00	A-C=	0.00
A-D=	0.00	A-D=	0.00
A-E=	0.00	A-E=	0.00
B-C=	0.00	B-C=	0.00
B-D=	0.00	B-D=	0.00
B-E=	0.00	B-E=	0.00
C-D=	0.00	C-D=	0.00
C-E=	0.00	C-E=	0.00
D-E=	0.00	D-E=	0.00

SET NUMBER 43 SAMPLES:TD-WET A1-E2		SET NUMBER 44 SAMPLES:TD-WET A3-E4	
CRITICAL DIFFERENCE 65.27		CRITICAL DIFFERENCE 37.56	
A=	335.96	A=	115.09
B=	519.83	B=	112.36
C=	690.08	C=	179.78
D=	658.30	D=	157.31
E=	889.84	E=	225.08
A-B=	-183.87	A-B=	2.73
A-C=	-354.12	A-C=	-64.69
A-D=	-322.34	A-D=	-42.22
A-E=	-553.88	A-E=	-109.99
B-C=	-170.25	B-C=	-67.42
B-D=	-138.47	B-D=	-44.95
B-E=	-370.01	B-E=	-112.72
C-D=	31.78	C-D=	22.47
C-E=	-199.76	C-E=	-45.30
D-E=	-231.54	D-E=	-67.77

TABLE 8-Continued

SET NUMBER 45 SAMPLES:TD-WET A5-E6	SET NUMBER 46 SAMPLES:TD-WET A7-E8
CRITICAL DIFFERENCE 0	CRITICAL DIFFERENCE 0
A= 0.00	A= 0.00
B= 26.44	B= 29.06
C= 0.00	C= 52.21
D= 27.02	D= 33.82
E= 42.90	E= 32.00
A-B= 0.00	A-B= 0.00
A-C= 0.00	A-C= 0.00
A-D= 0.00	A-D= 0.00
A-E= 0.00	A-E= 0.00
B-C= 0.00	B-C= 0.00
B-D= 0.00	B-D= 0.00
B-E= 0.00	B-E= 0.00
C-D= 0.00	C-D= 0.00
C-E= 0.00	C-E= 0.00
D-E= 0.00	D-E= 0.00

SET NUMBER 47 SAMPLES:TD-WET A9-E10	SET NUMBER 48 SAMPLES:TD-WET A11-E12
CRITICAL DIFFERENCE 27.29	CRITICAL DIFFERENCE 31.77
A= 304.86	A= 386.81
B= 225.18	B= 230.17
C= 291.47	C= 439.24
D= 111.91	D= 141.42
E= 320.52	E= 261.05
A-B= 79.68	A-B= 156.64
A-C= 13.39	A-C= -52.43
A-D= 192.95	A-D= 245.39
A-E= -15.66	A-E= 125.76
B-C= -66.29	B-C= -209.07
B-D= 113.27	B-D= 88.75
B-E= -95.34	B-E= -30.88
C-D= 179.56	C-D= 297.82
C-E= -29.05	C-E= 178.19
D-E= -208.61	D-E= -119.63

TABLE 8-Continued

SET NUMBER 49 SAMPLES:TD-WET A13-E14		SET NUMBER 50 SAMPLES:TD-WET A21-E22	
CRITICAL DIFFERENCE 65.73		CRITICAL DIFFERENCE 57.81	
A=	260.59	A=	181.37
B=	105.78	B=	385.90
C=	153.90	C=	328.92
D=	83.53	D=	286.24
E=	151.18	E=	296.91
A-B=	154.81	A-B=	-204.53
A-C=	106.69	A-C=	-147.55
A-D=	177.06	A-D=	-104.87
A-E=	109.41	A-E=	-115.54
B-C=	-48.12	B-C=	56.98
B-D=	22.25	B-D=	99.66
B-E=	-45.40	B-E=	88.99
C-D=	70.37	C-D=	42.68
C-E=	2.72	C-E=	32.01
D-E=	-67.65	D-E=	-10.67

SET NUMBER 51 SAMPLES:TD-WET A23-E24		SET NUMBER 52 SAMPLES:TD-WET A25-E26	
CRITICAL DIFFERENCE 0		CRITICAL DIFFERENCE 0	
A=	0.00	A=	0.00
B=	44.04	B=	0.00
C=	44.95	C=	0.00
D=	39.04	D=	0.00
E=	46.99	E=	0.00
A-B=	0.00	A-B=	0.00
A-C=	0.00	A-C=	0.00
A-D=	0.00	A-D=	0.00
A-E=	0.00	A-E=	0.00
B-C=	0.00	B-C=	0.00
B-D=	0.00	B-D=	0.00
B-E=	0.00	B-E=	0.00
C-D=	0.00	C-D=	0.00
C-E=	0.00	C-E=	0.00
D-E=	0.00	D-E=	0.00

TABLE 8-Continued

SET NUMBER 53 SAMPLES:TD-WET A27-E28		SET NUMBER 54 SAMPLES:TD-WET A29-E30	
CRITICAL DIFFERENCE 0		CRITICAL DIFFERENCE 27.38	
A=	0.00	A=	104.42
B=	0.00	B=	159.12
C=	0.00	C=	79.90
D=	0.00	D=	119.40
E=	0.00	E=	122.58
A-B=	0.00	A-B=	-54.70
A-C=	0.00	A-C=	24.52
A-D=	0.00	A-D=	-14.98
A-E=	0.00	A-E=	-18.16
B-C=	0.00	B-C=	79.22
B-D=	0.00	B-D=	39.72
B-E=	0.00	B-E=	36.54
C-D=	0.00	C-D=	-39.50
C-E=	0.00	C-E=	-42.68
D-E=	0.00	D-E=	-3.18

SET NUMBER 55 SAMPLES:TD-WET A31-E32		SET NUMBER 56 SAMPLES:TD-WET A33-E34	
CRITICAL DIFFERENCE 23.38		CRITICAL DIFFERENCE 0	
A=	114.63	A=	82.62
B=	121.90	B=	41.77
C=	81.04	C=	43.81
D=	68.55	D=	39.72
E=	96.25	E=	39.50
A-B=	-7.27	A-B=	0.00
A-C=	33.59	A-C=	0.00
A-D=	46.08	A-D=	0.00
A-E=	18.38	A-E=	0.00
B-C=	40.86	B-C=	0.00
B-D=	53.35	B-D=	0.00
B-E=	25.65	B-E=	0.00
C-D=	12.49	C-D=	0.00
C-E=	-15.21	C-E=	0.00
D-E=	-27.70	D-E=	0.00

Table 9

Summary of Scheffé's Test on ANOVAs

20% Add-on - Dry Tensiles

Fiber	Rayon		PE #1		MPE		R-PPY		A-PPY		PCP		PE #2	
Fiber ID codes	1,2		3,4		13,14		5,6		7,8		9,10		11,12	
Ionic nature Fiber	N		N		A		N		C		A		N	
Ionic nature Fiber Finish	C		C		A		A		C		C		C	
Fiber orientation in test sample	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD
Binder A *Rank	5	5	4	5	1.5	1.5	1.5	2	NS	5	3.5	3.5	4.5	2.5
Tg-18														
Ionic nature - Polymer - C														
Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	0	0	0	0	B,D,E	B,D,E	B,D	B,D	-	0	D	D	0	B,D
Binder B *Rank	3	2.5	4	4	4.5	4	4.5	5	NS	3	2	1.5	1	4
Tg-15														
Ionic nature - Polymer - N														
Ionic nature - Emulsifier - A														
Stronger at .05 than binder(s)	A	A	0	A	0	D	0	0	-	A	D,E	A,D,E	A,D,E	D
Binder C *Rank	3	2.5	1.5	1	1.5	1.5	1.5	2	NS	3	1	1.5	2	1
Tg-4														
Ionic nautre - Polymer - A														
Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	A	A	A,B,D	A,B,D,E	B,D,E	B,D,E	B,D	B,D	-	A	A,D,E	A,D,E	A,D	A,B,D,E
Binder D *Rank	3	2.5	4	3	4.5	5	4.5	4	NS	3	5	5	4.5	5
Tg-14														
Ionic nature - Polymer - N														
Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	A	A	0	A,B	0	0	0	B	-	A	0	0	0	0
Binder E *Rank	1	2.5	1.5	2	3	3	3	2	NS	1	3.5	3.5	3	2.5
Tg-7														
Ionic nature - Polymer - A														
Ionic nature - Emulsifier - A														
Stronger at .05 than binder(s)	A,B,D	A	A,B,D	A,B,D	B,D	B,D	B	B,D	-	A,C,D	D	D	D	B,D

*Rank Order - 1 = strongest
5 = weakest

NS = ANOVA showed no significant differences at .05

Table 9 - Continued

20% Add-on - Wet Tensiles

Fiber	Rayon		PE #1		MPE		R-PPY		A-PPY		PCP		PE #2	
Fiber ID codes	1,2		3,4		13,14		5,6		7,8		9,10		11,12	
Ionic nature Fiber	N		N		A		N		C		A		N	
Ionic nature Fiber Finish	C		C		A		A		C		C		C	
Fiber orientation in test sample	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD
Binder A *Rank	5	5	3.5	4.5	NS	1.0	5	NS	5	NS	3	2.5	2.5	2
Tg-18 Ionic nature - Polymer - C Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	0	0	0	0	-	B,C,D,E	0	-	0	-	D	B,D	D	B,D,E
Binder B *Rank	1	4	3.5	4.5	NS	4.5	2.5	NS	4	NS	3	4	4.5	3.5
Tg-15 Ionic nature - Polymer - N Ionic nature - Emulsifier - A														
Stronger at .05 than binder(s)	A,C,D	A	0	0	-	0	A,C	-	A	-	D	D	0	D
Binder C *Rank	3.5	2.5	3.5	2.5	NS	2.5	4	NS	2	NS	1	2.5	1	1
Tg-4 Ionic nature - Polymer -A Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	A	A,B	0	A,B	-	B,D	A	-	A,B	-	B,D,E	B,D	A,B,D,E	A,B,D,E
Binder D *Rank	3.5	2.5	3.5	2.5	NS	5	2.5	NS	2	NS	5	5	4.5	5
Tg-14 Ionic nature - Polymer - N Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	A	A,B	0	A,B	-	0	A,C	-	A,B	-	0	0	0	0
Binder E *Rank	2	1	1	1	NS	2.5	1	NS	2	NS	3	1	2.5	3.5
Tg-7 Ionic nature - Polymer - A Ionic nature - Emulsifier - A														
Stronger at .05 than binder(s)	A,D	A,B, C,D	A,B, C,D	A,B, C,D	-	B,D	A,B, C,D	-	A,B	-	D	B,C,D	D	D

*Rank Order - 1 = strongest
5 = weakest

NS = ANOVA showed no significant differences at .05

Table 9 - Continued

5% Dry Add-on - Dry Tensiles

Fiber	Rayon		PE #1		MPE		R-PPY		A-PPY		PCP		PE #2	
Fiber ID codes	21,22		23,24		33,34		25,26		27,28		29,30		31,32	
Ionic nature Fiber	N		N		A		N		C		A		N	
Ionic nature Fiber Finish	C		C		A		A		C		C		C	
Fiber orientation in test sample	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD
Binder A *Rank	NS	5	5	NS	NS	NS	5	NS	5	NS	4	4.5	3.5	NS
Tg-18 Ionic nature - Polymer - C Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	-	0	0	-	-	-	0	-	0	-	0	0	D	-
Binder B *Rank	NS	2	2.5	NS	NS	NS	3.5	NS	3	NS	1	1.5	2	NS
Tg-15 Ionic nature - Polymer - N Ionic nature - Emulsifier - A														
Stronger at .05 than binder(s)	-	A,D	A	-	-	-	A	-	A	-	A,C,D,E	A,C,D	C,D	-
Binder C *Rank	NS	2	2.5	NS	NS	NS	2	NS	1	NS	4	4.5	3.5	NS
Tg-4 Ionic nature - Polymer - A Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	-	A,D	A	-	-	-	A,B,D	-	A,B,D	-	0	0	D	-
Binder D *Rank	NS	4	2.5	NS	NS	NS	3.5	NS	3	NS	2	3	5	NS
Tg-14 Ionic nature - Polymer - N Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	-	A	A	-	-	-	A	-	A	-	A,C	A	0	-
Binder E *Rank	NS	2	2.5	NS	NS	NS	1	NS	3	NS	4	1.5	1	NS
Tg-7 Ionic nature - Polymer - A Ionic nature - Emulsifier - A														
Stronger at .05 than binder(s)	-	A,D	A	-	-	-	A,B,C,D	-	A	-	0	A,C,D	A,B,C,D	-

*Rank Order - 1 = strongest
2 = weakest

NS = ANOVA showed no significant differences at .05

5% Dry Add-on - Wet Tensiles

Table 9 - Continued

Fiber	Rayon		PE #1		MPE		R-PPY		A-PPY		PCP		PE #2	
Fiber ID codes	21,22		23,24		33,34		25,26		27,28		29,30		31,32	
Ionic nature Fiber	N		N		A		N		C		A		N	
Ionic nature Fiber Finish	C		C		A		A		C		C		C	
Fiber orientation in test sample	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD	MD	TD
Binder A *Rank	5	5	5	NS	NS	NS	5	NS	5	NS	4	4.5	3	2
Tg-18 Ionic nature - Polymer - C Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	0	0	0	-	-	-	0	-	0	-	0	0	D	C,D
Binder B *Rank	1	1	2.5	NS	NS	NS	1.5	NS	2.5	NS	1	1	1	1
Tg-15 Ionic nature - Polymer - N Ionic nature - Emulsifier - A														
Stronger at .05 than binder(s)	A,C,D	A,D,E	A	-	-	-	A,C,D	-	A	-	A,C,D,E	A,C,D,E	C,D	C,D,E
Binder C *Rank	3	3	2.5	NS	NS	NS	3.5	NS	2.5	NS	4	4.5	3	4.5
Tg-4 Ionic nature - Polymer - A Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	A	A	A	-	-	-	A	-	A	-	0	0	D	0
Binder D *Rank	3	3	2.5	NS	NS	NS	3.5	NS	2.5	NS	2	2.5	5	4.5
Tg-14 Ionic nature - Polymer - N Ionic nature - Emulsifier - N														
Stronger at .05 than binder(s)	A	A	A	-	-	-	A	-	A	-	A,C,E	C	0	0
Binder E *Rank	3	3	2.5	NS	NS	NS	1.5	NS	2.5	NS	4	2.5	3	3
Tg-7 Ionic nature - Polymer - A Ionic nature - Emulsifier - A														
Stronger at .05 than binder(s)	A	A	A	-	-	-	A,C,D	-	A	-	0	C	D	D

*Rank Order - 1 = strongest
2 = weakest
NS = ANOVA showed no significant differences at .05

APPENDIX C

MEANS AND STANDARD DEVIATIONS OF NORMALIZED DATA

Table 10

Means and Standard Deviations of Normalized Data

Sample ID.	Dry MD	Dry SD	Wet MD	Wet SD	Dry TD	Dry SD	Wet TD	Wet SD
A1	1253	212.06	695	125.07	558	57.75	341	26.71
A2	1244	241.21	667	176.48	568	50.98	331	9.72
B1	2701	238.39	1335	237.81	1571	231.39	508	32.09
B2	2892	274.36	1625	129.76	1616	232.55	531	40.34
C1	3196	253.00	1489	105.34	1920	95.72	726	47.87
C2	3055	183.15	1326	107.66	1771	100.24	654	41.25
D1	3037	286.35	1416	68.08	1380	48.65	695	18.38
D2	3083	245.12	1280	97.30	1548	48.65	622	9.18
E1	3659	306.75	1535	167.90	1902	349.82	990	39.70
E2	3287	338.76	1303	151.44	1798	381.45	790	40.96
A3	386	71.59	245	41.18	241	20.09	108	11.57
A4	399	98.24	241	36.46	257	23.53	122	0
B3	549	19.38	239	46.67	346	11.46	119	0
B4	508	22.53	204	32.85	326	17.11	106	29.99
C3	1108	92.42	241	31.72	595	41.79	181	20.07
C4	931	92.58	262	38.24	563	41.38	179	34.46
D3	518	51.73	227	47.99	386	13.92	177	0
D4	440	26.98	198	28.92	400	13.53	138	10.99
E3	849	220.70	540	192.76	522	40.26	222	20.13
E4	972	250.37	595	223.31	468	23.21	229	23.21
A5	672	123.37	91	20.50	104	0	0	0
A6	713	144.06	91	31.65	108	3.19	0	0
B5	377	61.38	194	37.40	50	0	25	0
B6	338	46.14	231	46.94	41	0	27	0
C5	695	163.02	151	15.17	114	15.33	0	0
C6	722	176.73	156	20.78	112	6.33	0	0
D5	444	46.26	211	36.55	68	0	27	0
D6	490	67.76	240	55.92	75	15.42	27	0
E5	554	25.27	262	13.48	99	14.13	42	0
E6	640	39.94	315	43.26	108	8.40	44	0
A7	545	48.05	91	14.18	53	6.67	0	0
A8	499	90.49	81	18.33	51	6.67	0	0
B7	572	46.68	181	25.01	87	5.98	31	0
B8	468	30.66	141	15.94	82	2.42	27	6.06
C7	499	92.19	203	38.67	82	0	51	0
C8	454	20.83	205	21.92	79	6.16	53	0
D7	421	65.92	205	18.90	81	0	35	0
D8	429	46.56	205	18.62	80	11.12	33	0
E7	572	114.01	218	32.76	90	10.01	30	0
E8	590	95.39	228	36.98	100	0	34	0
A9	1103	207.71	590	60.92	631	21.13	309	9.28
A10	1221	220.30	608	60.00	667	23.16	301	8.83
B9	1403	225.37	504	92.75	772	62.01	217	16.74
B10	1462	241.57	549	67.60	826	41.87	233	9.59

Table 10 - Continued

Sample ID.	Dry		Wet		Dry		Wet	
	MD	SD	MD	SD	TD	SD	TD	SD
C9	1752	200.25	645	20.38	781	15.63	297	15.63
C10	1675	228.58	581	19.90	699	17.45	286	20.18
D9	776	177.44	319	35.97	431	18.35	114	9.99
D10	745	163.06	309	29.03	426	33.41	109	11.27
E9	1026	162.11	499	63.54	572	29.67	318	11.19
E10	1135	260.24	545	86.84	636	23.30	323	20.19
A11	890	166.24	490	70.57	640	6.48	375	18.73
A12	953	187.42	536	50.95	645	9.42	399	9.42
B11	1439	150.79	430	101.12	430	52.58	230	10.49
B12	1426	199.84	408	77.35	437	41.00	231	20.48
C11	1380	170.77	717	100.60	799	28.84	443	19.21
C12	1348	136.06	658	124.79	767	27.69	435	18.14
D11	617	170.77	319	72.71	263	37.56	135	10.82
D12	645	148.02	332	94.87	284	42.57	148	18.43
E11	1117	332.43	531	81.11	627	33.87	266	11.26
E12	1062	377.11	486	101.41	522	45.50	256	19.70
A13	649	41.21	271	63.26	495	10.84	256	10.84
A14	667	36.54	285	67.49	504	21.91	266	0
B13	254	28.78	174	52.39	193	20.99	102	20.99
B14	283	37.91	194	54.21	201	18.28	110	18.28
C13	663	69.87	249	3.589	522	9.97	156	17.30
C14	640	63.84	239	63.84	513	18.99	152	18.99
D13	243	39.70	142	21.33	157	10.78	82	67.83
D14	269	41.76	150	25.12	162	11.09	85	69.84
E13	463	45.53	280	63.14	264	30.51	152	11.50
E14	468	30.09	270	51.77	250	22.91	151	11.43
A21	414	56.94	284	29.60	237	54.99	162	18.00
A22	486	74.85	340	24.47	255	25.81	201	0
B21	867	189.25	663	45.84	468	30.31	370	45.84
B22	1121	265.59	749	156.83	554	83.79	403	63.34
C21	1426	137.88	622	48.40	531	77.27	345	21.19
C22	1230	152.83	568	70.52	586	78.47	312	10.85
D21	1167	108.51	536	71.64	351	10.32	258	10.32
D22	1280	122.34	572	70.85	393	17.88	315	10.30
E21	1516	127.41	663	49.37	504	16.28	303	37.58
E22	1389	133.82	577	50.57	486	19.52	291	10.30
A23	0	0	0	0	0	0	0	0
A24	0	0	0	0	0	0	0	0
B23	72	29.43	63	10.13	22	0	45	0
B24	87	40.53	74	19.38	43	0	43	0
C23	76	33.99	58	12.24	44	0	44	0
C24	64	19.04	59	12.43	45	0	45	0
D23	62	8.70	59	0	50	11.24	39	0
D24	66	10.67	59	0	50	8.91	39	0
E23	57	21.28	67	10.62	48	0	48	0
E24	65	19.43	74	10.37	46	0	46	0

Table 10 - Continued

Sample ID	Dry		Wet		Dry		Wet	
	MD	SD	MD	SD	TD	SD	TD	SD
A25	0	0	0	0	0	0	0	0
A26	0	0	0	0	0	0	0	0
B25	52	28.81	71	18.37	0	0	0	0
B26	48	13.23	73	8.64	0	0	0	0
C25	76	18.60	52	13.59	0	0	0	0
C26	74	18.12	44	0	0	0	0	0
D25	47	16.11	59	20.83	0	0	0	0
D26	47	23.92	44	0	0	0	0	0
E25	107	18.85	79	19.64	0	0	0	0
E26	110	27.89	90	9.11	0	0	0	0
A27	0	0	0	0	0	0	0	0
A28	0	0	0	0	0	0	0	0
B27	42	17.00	39	15.98	0	0	0	0
B28	44	15.00	40	9.32	0	0	0	0
C27	73	15.34	40	13.41	0	0	0	0
C28	67	21.18	39	0	0	0	0	0
D27	45	11.21	28	5.59	0	0	0	0
D28	38	9.97	29	6.51	0	0	0	0
E27	54	7.63	32	0	0	0	0	0
E28	51	8.96	32	0	0	0	0	0
A29	213	38.84	153	19.12	105	0	105	0
A30	223	74.42	190	53.25	112	18.60	104	28.39
B29	472	72.32	262	47.47	230	17.70	166	20.42
B30	545	92.65	387	49.90	253	28.43	152	21.47
C29	232	48.91	129	0	107	21.45	64	0
C30	250	47.88	183	13.00	117	28.02	95	10.58
D29	370	73.71	247	36.15	189	25.41	132	0
D30	352	65.58	237	31.43	138	22.23	107	12.80
E29	268	31.64	183	40.00	224	44.75	112	0
E30	298	48.19	196	24.36	213	33.92	133	0
A31	216	42.96	162	23.46	144	17.99	115	17.59
A32	220	44.18	118	11.13	130	11.74	114	11.74
B31	269	46.62	140	25.46	164	22.53	128	22.53
B32	281	39.88	161	25.80	177	11.08	115	0
C31	218	43.78	117	16.88	162	0	81	0
C32	210	46.48	109	23.02	153	23.30	81	0
D31	128	45.05	68	17.75	140	12.23	68	12.23
E31	387	30.63	147	35.16	186	11.15	116	0
E32	355	28.70	128	0	154	12.34	77	12.34
A33	41	13.92	83	0	20	0	83	0
A34	49	10.67	82	0	20	0	82	0
B33	71	43.60	84	0	63	0	42	0
B34	95	29.37	83	0	91	33.45	41	0

Table 10 - Continued

Sample ID	Dry MD	Dry SD	Wet MD	Wet SD	Dry TD	Dry SD	Wet TD	Wet SD
C33	66	0	89	0	44	0	44	0
C34	66	0	88	0	44	0	44	0
D33	95	8.82	71	18.87	40	0	40	0
D34	88	38.94	72	10.90	40	0	40	0
E33	74	21.30	70	10.63	39	0	39	0
E34	84	16.84	76	16.84	40	0	40	0

Table 11

Raw Tensile Data (Pounds/Inches)

Sample ID	Dry MD	SD	Wet MD	SD	Dry TD	SD	Wet TD	SD
A1	3.59	.6066	1.99	.3578	1.59	.1652	.97	.0764
A2	3.69	.7144	1.98	.5227	1.69	.1510	.98	.0288
B1	8.42	.7429	4.16	.7411	4.90	.7211	1.65	.1000
B2	8.28	.7855	4.66	.3715	4.63	.6658	1.52	.1155
C1	10.20	.8075	4.76	.3362	6.73	.3055	2.32	.1528
C2	9.80	.5874	4.54	.3453	4.63	.3215	2.10	.1323
D1	9.54	.8988	4.45	.2137	4.33	.1527	2.18	.0577
D2	9.68	.7694	4.02	.3154	4.86	.1527	1.98	.0288
E1	12.20	1.0222	5.11	.5595	6.34	1.1657	3.30	.1323
E2	10.60	1.0941	4.21	.4891	5.81	1.2320	2.55	.1323
A3	.96	.1782	.61	.1025	.60	.0500	.27	.0288
A4	.98	.2409	.59	.0894	.63	.0577	.30	0
B3	1.38	.0487	.60	.1173	.87	.0288	.30	0
B4	1.29	.0574	.52	.0837	.83	.0436	.27	.0764
C3	2.76	.2302	.60	.0790	1.48	.1041	.45	.0500
C4	2.34	.2329	.66	.0962	1.42	.1041	.45	.0867
D3	1.34	.1342	.59	.1245	1.42	.0361	.40	0
D4	1.15	.0707	.52	.0758	1.05	.0500	.36	.0288
E3	2.11	.5482	1.34	.4788	1.30	.1000	.55	.0500
E4	2.41	.6215	1.48	.5552	1.16	.0577	.57	.0572
A5	2.59	.4761	.35	.0791	.40	0	0	0
A6	2.56	.5189	.34	.1140	.39	.0115	0	0
B5	1.49	.2434	.77	.1483	.20	0	.10	0
B6	1.23	.1681	.84	.1710	.15	0	.10	0
C5	2.61	.6138	.57	.0571	.43	.0577	0	0
C6	2.63	.6448	.57	.0758	.41	.0231	0	0
D5	1.64	.1710	.90	.1351	.25	0	.10	0
D6	1.84	.2535	.90	.2092	.28	.0577	.10	0
E5	1.96	.0894	.93	.0447	.35	.0500	.15	0
E6	2.20	.1369	1.08	.1483	.37	.0288	.15	0
A7	2.36	.2074	.40	.0612	.23	.0288	0	0
A8	2.15	.3905	.35	.0791	.22	.0288	0	0
B7	2.76	.2247	.87	.1204	.42	.0288	.15	0
B8	2.20	.1458	.67	.0758	.39	.0115	.13	.0288
C7	2.44	.4491	.99	.1884	.40	0	.25	0
C8	2.13	.0974	.96	.1025	.37	.0288	.25	0
D7	1.83	.2869	.89	.0821	.35	0	.15	0
D8	1.93	.2093	.92	.0837	.35	.0500	.15	0
E7	2.86	.5694	1.09	.1636	.45	.0500	.15	0
E8	2.96	.4775	1.14	.1851	.50	0	.17	0
A9	3.43	.6447	1.83	.1891	1.96	.0656	.96	.0288
A10	3.98	.7182	1.98	.1956	2.17	.0755	.98	.0288

Table 11 - Continued

Sample ID	Dry MD	SD	Wet MD	SD	Dry TD	SD	Wet TD	SD
B9	4.19	.6731	1.51	.2770	2.31	.1852	.65	.0500
B10	4.39	.7258	1.65	.2031	2.48	.1258	.70	0
C9	5.61	.6407	2.06	.0652	2.50	.0500	.95	.0500
C10	4.80	.6548	1.67	.0570	2.00	.0500	.82	.0578
D9	2.24	.5116	.92	.1037	1.24	.0529	.33	.0288
D10	1.90	.4168	.79	.0742	1.09	.0854	.28	.0288
E9	2.64	.4174	1.29	.1636	1.47	.0764	.82	.0288
E10	2.81	.6446	1.35	.2151	1.57	.0577	.80	.0500
A11	2.38	.4438	1.31	.1884	1.71	.0173	1.00	.0500
A12	2.91	.5727	1.64	.1557	1.97	.0288	1.20	.0288
B11	3.95	.4138	1.18	.2775	1.18	.1443	.63	.0288
B12	4.02	.5630	1.15	.2179	1.29	.1155	.63	.0577
C11	4.14	.5128	2.15	.3021	2.40	.0866	1.33	.0577
C12	3.72	.3667	1.82	.3439	2.12	.0763	1.20	.0500
D11	1.64	.4547	.85	.1936	.70	.1000	.36	.0288
D12	1.75	.4016	.90	.2574	.77	.1155	.40	.0500
E11	2.85	.8500	1.36	.2074	1.60	.0866	.68	.0288
E12	2.70	.9572	1.23	.2080	1.33	.1154	.65	.0500
A13	1.73	.1095	.72	.1681	1.32	.0288	.68	.0288
A14	1.76	.0962	.75	.1777	1.33	.0577	.70	0
B13	.70	.0791	.48	.1440	.53	.0577	.28	.0577
B14	.78	.1037	.53	.1037	.53	.1483	.30	.0500
C13	1.92	.2019	.72	.1037	1.51	.0288	.45	.0500
C14	1.68	.1681	.63	.1681	1.35	.0500	.40	.0500
D13	.65	.1061	.38	.0570	.42	.0288	.22	.1813
D14	.69	.1084	.39	.0652	.42	.0288	.22	.1813
E13	1.16	.1140	.70	.1581	.66	.0764	.38	.0288
E14	1.18	.0758	.68	.1304	.63	.0577	.38	.0288
A21	1.15	.1581	.79	.0822	.66	.1527	.45	.0500
A22	1.09	.1673	.76	.0547	.57	.0577	.45	0
B21	2.18	.4764	1.67	.1154	1.18	.0763	.93	.1154
B22	2.70	.6403	1.81	.3781	1.33	.2020	.97	.1527
C21	3.84	.3715	1.68	.1304	1.43	.2082	.93	.0571
C22	3.27	.4055	1.50	.1871	1.56	.2082	.83	.0288
D21	3.26	.3029	1.50	.2000	.98	.0288	.72	.0288
D22	3.58	.3421	1.64	.1981	1.10	.0500	.88	.0288
E21	4.66	.3912	2.04	.1516	1.55	.0500	.93	.1154
E22	4.10	.3742	1.70	.1414	1.43	.0577	.86	.0288
A23	0	0	0	0	.15	0	0	0
A24	0	0	0	0	0	0	0	0
B23	.16	.0651	.14	.0224	.05	0	.10	0
B24	.20	.0935	.17	.0447	.10	0	.10	0
C23	.17	.0758	.13	.0273	.10	0	.10	0
C24	.14	.0418	.13	.0273	.10	0	.10	0
D23	.16	.0223	.15	0	.13	.0288	.10	0
D24	.17	.0273	.15	0	.13	.0288	.10	0

Table 11 - Continued

Sample ID	Dry MD	Dry SD	Wet MD	Wet SD	Dry TD	Dry SD	Wet TD	Wet SD
E23	.12	.0447	.14	.0223	.10	0	.10	0
E24	.14	.0418	.16	.0223	.10	0	.10	0
A25	0	0	0	0	0	0	0	0
A26	0	0	0	0	0	0	0	0
B25	.16	.0894	.22	.0570	0	0	0	0
B26	.14	.0418	.23	.0273	0	0	0	0
C25	.25	.0612	.17	.0447	0	0	0	0
C26	.25	.0612	.15	0	0	0	0	0
D25	.16	.0547	.20	.0707	0	0	0	0
D26	.16	.0821	.15	0	0	0	0	0
E25	.31	.0547	.23	.0570	0	0	0	0
E26	.33	.0836	.27	.2073	0	0	0	0
A27	0	0	0	0	0	0	0	0
A28	0	0	0	0	0	0	0	0
B27	.16	.0651	.15	.0612	0	0	0	0
B28	.17	.0570	.15	.0354	0	0	0	0
C27	.31	.0651	.17	.0570	0	0	0	0
C28	.28	.0821	.15	0	0	0	0	0
D27	.18	.0477	.11	.0223	0	0	0	0
D28	.16	.0418	.12	.0273	0	0	0	0
E27	.25	.0353	.15	0	0	0	0	0
E28	.24	.0418	.15	0	0	0	0	0
A29	.61	.1140	.44	.0547	.30	0	.30	0
A30	.60	.2000	.51	.1431	.30	.0500	.28	.0763
B29	1.34	.2043	.74	.1341	.65	.0500	.47	.0577
B30	1.47	.2490	1.04	.1341	.68	.0764	.43	.0577
C29	.56	.1140	.30	0	.25	.0500	.15	0
C30	.68	.1304	.50	.0354	.32	.0763	.26	.0288
D29	.84	.1674	.56	.0821	.43	.0577	.30	0
D30	.89	.1475	.60	.0707	.35	.0500	.27	.0288
E29	.60	.0707	.41	.0894	.50	.1000	.25	0
E30	.67	.1095	.41	.0548	.48	.0763	.25	0
A31	.60	.1275	.45	.0707	.40	.0500	.32	.0288
A32	.54	.1084	.33	.0273	.32	.0288	.28	.0288
B31	.69	.1194	.36	.0652	.42	.0577	.33	.0577
B32	.73	.1037	.42	.0671	.46	.0288	.30	0
C31	.54	.1034	.29	.0418	.40	0	.20	0
C32	.52	.1151	.27	.0570	.38	.0577	.20	0
D31	.30	.1061	.16	.0418	.33	.0288	.16	.0288
D32	.33	.0908	.16	.0418	.40	.0500	.16	.0288
E31	1.00	.0791	.48	.0908	.38	.0288	.30	0
E32	.83	.0670	.30	0	.36	.0288	.18	.0288
A33	.10	.0353	.20	0	.05	0	.20	0
A34	.12	.0274	.20	0	.05	0	.20	0
B33	.17	.1036	.20	0	.15	0	.10	0

Table 11 - Continued

Sample ID	Dry MD	Dry SD	Wet MD	Wet SD	Dry TD	Dry SD	Wet TD	Wet SD
B34	.23	.0670	.20	0	.22	.0763	.10	0
C33	.15	0	.20	0	.10	0	.10	0
C34	.15	0	.20	0	.10	0	.10	0
D33	.24	.0223	.18	.0447	.10	0	.10	0
D34	.22	.0975	.18	.0273	.10	0	.10	0
E33	.19	.0547	.18	.0273	.10	0	.10	0
E34	.21	.0418	.19	.0418	.10	0	.10	0

Table 12

Thickness Measurements in Mils

Average of 10 Tests Samples	Mils	Average of 10 Tests Samples	Mils
A1.1	8.0	A21.22	9.0
B1.2	8.0	B21.22	9.0
C1.2	8.0	C21.22	9.0
D1.2	8.0	D21.22	9.0
E1.2	8.0	E21.22	9.0
A3.4	14.0	A23.24	14.5
B3.4	13.5	B23.24	14.0
C3.6	13.0	C23.24	13.5
D3.4	13.0	D23.24	14.5
C3.4	13.5	E23.24	15.5
A5.6	24.0	A25.26	23.0
B5.6	24.0	B25.26	23.0
C5.6	23.5	C25.26	23.0
D5.6	26.5	D25.26	24.0
E5.6	25.0	E25.26	24.5
A7.8	30.0	A27.28	32.0
B7.8	28.0	B27.28	30.0
C7.8	27.5	C27.28	30.0
D7.8	27.5	D27.28	29.0
E7.8	29.0	E27.28	30.0
A9.10	18.0	A29.30	15.0
B9.10	19.5	B29.30	16.5
C9.10	18.0	C29.30	14.5
D9.10	17.5	D29.30	15.5
E9.10	18.0	E29.30	15.5
A11.12	15.0	A31.32	13.0
B11.12	15.5	B31.32	13.5
C11.12	16.5	C31.32	14.0
D11.12	14.5	D31.32	13.5
E11.12	16.0	E31.32	14.0
A13.14	16.5	A33.34	17.0
B13.14	17.0	B33.34	17.0
C13.14	17.5	C33.34	15.5
D13.14	16.5	D33.34	15.0
E13.14	17.0	E33.34	15.0

Table 13

Wet and Dry Pickup Measurements: 20% Binder Solids, Water Only, and Water Plus .20% Wetting Agent

Binder	Untreated Weight (grams)	Treated Wet Weight (grams)	Treated Dry Weight (grams)	Actual Pickup % Wet	Actual Pickup % Dry Add-On
Fiber - Rayon, Codes 1,2,21,22					
A	3.40	9.00	4.10	164.71	20.59
B	3.40	8.95	4.15	163.24	22.06
C	3.40	8.60	4.10	152.94	20.59
D	3.20	8.60	3.85	168.75	20.31
E	3.40	8.90	4.05	161.76	19.12
Water only	0.9268	2.6831	-	189.50	-
Water + WA*	1.0750	2.9340	-	174.21	-
Fiber - PE #1, Codes 3,4,23,24					
A	2.90	5.90	3.50	103.45	20.69
B	2.65	7.30	3.20	175.47	20.75
C	2.55	5.55	3.05	117.65	19.61
D	2.65	5.50	3.20	107.55	20.75
E	2.15	4.50	2.60	109.30	20.93
Water only	0.6632	2.3779	-	258.55	-
Water + WA*	0.7840	1.4539	-	85.45	-
Fiber - MPE, Codes 13,14,33,34					
A	2.70	7.50	3.50	177.78	29.63
B	2.80	7.25	3.65	158.93	30.63
C	2.90	6.00	3.60	100.90	31.03
D	3.00	7.30	3.90	143.33	30.00
E	2.70	6.90	3.55	155.56	31.48
Water only	0.8230	2.8144	-	241.97	-
Water + WA*	0.9757	1.8292	-	87.47	-

Table 13 - Continued

Binder	Untreated Weight (grams)	Treated Wet Weight (grams)	Treated Dry Weight (grams)	Actual Pickup % Wet	Actual Pickup % Dry Add-On
Fiber - PCP, Codes 9,10,29,30					
A	4.00	9.80	5.20	145.00	30.00
B	3.60	9.40	4.75	161.11	31.94
C	3.30	8.25	4.30	150.00	30.30
D	3.90	9.90	5.10	153.85	30.77
E	3.45	9.70	4.50	181.20	30.43
Water only	1.1400	3.9116	-	243.12	-
Water + WA*	1.3534	3.7550	-	177.45	-
Fiber - PE #2, Codes 11,12,31,32					
A	2.90	7.10	3.80	144.83	31.03
B	2.95	8.30	3.90	181.36	32.20
C	3.20	7.50	4.20	134.38	31.25
D	2.70	6.40	3.55	137.04	31.48
E	2.60	5.90	3.40	126.92	30.77
Water only	0.7556	2.5541	-	238.02	-
Water + WA*	0.8790	1.8336	-	108.60	-
Fiber - R-PPY, Codes 5,6,25,26					
A	4.90	9.20	6.00	87.76	22.45
B	6.40	14.30	7.70	123.44	20.31
C	6.50	12.30	7.75	89.23	19.23
D	6.50	12.70	7.70	95.38	18.46
E	6.00	11.40	7.20	90.00	20.00
Water only	3.2066	11.0070	-	243.06	-
Water + WA*	2.8424	4.9980	-	75.84	-
Fiber - A-PPY, Codes 7,8,27,28					
A	8.20	15.40	9.80	87.80	19.51
B	8.80	18.80	10.80	113.60	22.73
C	8.70	16.30	10.45	87.36	20.11
D	8.80	17.70	10.70	101.14	21.59
E	7.80	14.90	9.40	91.03	20.51
Water only	4.6024	14.1232	-	206.87	-
Water + WA*	3.6212	6.3366	-	74.99	-

*WA = wetting agent

Table 14

Measurement of Dry Binder Add-On on Treated Webs

		Untreated Web		Treated/Cured Web		
Sample	Inches^2	Actual Wt. (grams)	Equivalent (gm/yd^2)	Actual Wt. (grams)	Equivalent (gm/yd^2)	% Day Add-on
A1	165.41	3.80	29.77	4.70	36.82	23.68
A2	166.60	4.00	31.13	4.90	38.12	22.50
B1	165.41	4.30	33.69	5.15	40.11	19.76
B2	165.41	3.90	30.58	4.70	36.85	20.51
C1	165.60	4.40	34.43	5.25	41.08	19.32
C2	161.66	4.30	34.47	5.15	41.28	19.77
D1	166.80	4.30	33.41	5.20	40.40	20.93
D2	166.80	4.30	33.41	5.20	40.40	20.93
E1	163.20	4.50	35.74	5.40	42.85	20.00
E2	168.36	4.50	34.64	5.40	41.57	20.50
A3	161.84	3.30	26.43	4.00	32.04	21.21
A4	158.12	3.20	26.23	3.85	31.56	20.31
B3	161.46	3.40	26.83	4.10	32.35	20.58
B4	159.46	3.30	27.05	4.00	32.79	21.21
C3	157.95	3.20	26.65	3.85	32.06	20.31
C4	159.30	3.30	26.85	3.98	32.38	20.61
D3	159.12	3.45	28.10	4.10	33.39	18.84
D4	155.61	3.40	28.32	4.05	33.73	19.12
E3	158.12	3.20	26.23	3.90	31.97	21.88
E4	157.95	3.20	26.26	3.90	32.00	21.88
A5	172.20	5.40	40.64	6.60	49.67	22.22
A6	170.50	5.00	38.00	6.10	46.36	22.00
B5	168.84	5.45	41.83	6.65	51.04	22.02
B6	171.36	5.15	38.95	6.20	46.89	20.38
C5	179.20	5.50	39.77	6.70	48.46	21.82
C6	171.12	5.05	38.25	6.20	46.96	22.78
D5	170.28	5.10	38.82	6.25	47.58	22.55
D6	173.60	5.25	38.82	6.45	48.15	22.86
E5	173.60	4.95	36.95	6.10	45.54	23.23
E6	179.20	4.95	35.80	6.10	44.12	23.47
A7	175.00	6.20	45.92	7.50	55.55	20.97
A8	175.00	6.10	45.17	7.50	55.54	22.95
B7	173.60	6.90	51.51	8.30	61.96	20.29
B8	173.60	6.80	50.76	8.20	61.21	20.59
C7	173.60	6.80	50.76	8.40	62.70	23.53
C8	168.00	6.30	48.60	7.80	60.18	23.81
D7	182.00	6.40	45.57	7.85	55.90	22.66
D8	179.20	6.60	47.73	8.00	57.86	21.21
E7	175.00	7.20	53.32	8.68	64.28	20.56
E8	175.00	7.20	53.32	8.70	64.43	20.83

Table 14 - Continued

Sample	Inches^2	Untreated Web Actual Wt. (grams)	Untreated Web Equivalent (gm/yd^2)	Treated/Cured Web Actual Wt. (grams)	Treated/Cured Web Equivalent (gm/yd^2)	% Day Add-on
A9	165.41	4.20	32.80	5.10	39.95	21.43
A10	166.80	4.40	34.19	5.40	41.96	22.73
B9	165.20	4.00	31.38	4.90	38.44	22.50
B10	164.22	4.00	31.57	4.90	38.67	22.50
C9	166.80	4.40	34.19	5.30	41.18	20.45
C10	161.66	3.80	30.46	4.60	36.87	21.05
D9	163.80	3.90	30.86	4.69	37.11	20.26
D10	165.41	3.50	27.42	4.20	32.90	20.00
E9	168.19	3.50	26.97	4.30	33.14	22.86
E10	162.63	3.30	26.30	4.00	31.88	21.21
A11	164.02	3.60	28.41	4.35	34.36	20.83
A12	161.46	4.00	32.11	4.90	39.33	22.50
B11	161.46	3.60	28.90	4.40	35.32	22.22
B12	162.63	3.80	30.28	4.55	36.26	19.74
C11	162.63	4.00	31.88	4.85	38.65	21.25
C12	162.63	3.70	29.49	4.45	35.47	20.27
D11	162.63	3.60	28.69	4.30	34.27	19.44
D12	161.46	3.60	28.90	4.35	34.92	20.83
E11	161.46	3.40	27.29	4.10	32.91	20.59
E12	162.63	3.40	27.09	4.10	32.67	20.59
A13	155.40	3.35	27.94	4.10	34.20	22.39
A14	156.80	3.40	28.10	4.10	33.89	20.59
B13	157.50	3.60	29.62	4.30	35.38	19.44
B14	154.56	3.50	29.34	4.20	35.21	20.00
C13	156.80	3.70	30.58	4.50	37.19	21.62
C14	156.80	3.38	27.93	4.10	33.89	21.30
D13	152.55	3.40	28.88	4.05	34.40	19.12
D14	157.07	3.40	28.05	4.05	33.41	19.12
E13	156.80	3.25	26.86	3.90	32.23	20.00
E14	161.88	3.40	27.22	4.05	32.42	19.12
A21	164.22	4.30	33.93	4.53	35.74	5.34
A22	166.60	3.50	27.22	3.70	28.77	5.71
B21	168.00	4.00	30.86	4.20	32.40	5.40
B22	162.84	3.70	29.44	3.90	31.03	5.40
C21	164.40	4.20	33.11	4.40	34.68	4.76
C22	166.98	4.20	32.60	4.40	34.15	4.76
D21	166.98	4.40	34.15	4.63	35.93	5.23
D22	165.60	4.40	34.43	4.60	35.99	4.55
E21	165.60	4.80	37.57	5.05	39.52	5.21
E22	168.70	4.70	36.11	4.95	38.03	5.32
A23	161.00	3.35	26.97	3.52	28.34	5.07
A24	161.00	4.00	32.20	4.20	33.81	5.00
B23	157.95	3.30	27.08	3.47	28.47	5.15
B24	170.20	3.70	28.17	3.90	29.69	5.40

Table 14 - Continued

Sample	$Inches^2$	Untreated Web		Treated/Cured Web		% Day Add-on
		Actual Wt. (grams)	Equivalent (gm/yd^2)	Actual Wt. (grams)	Equivalent (gm/yd^2)	
C23	160.29	3.40	27.49	3.55	28.70	4.41
C24	159.12	3.30	26.88	3.47	28.26	5.15
D23	159.12	3.85	31.36	4.10	32.99	5.19
D24	155.44	3.75	31.27	3.95	32.94	5.33
E23	160.65	3.20	25.82	3.35	27.03	4.69
E24	159.12	3.25	26.47	3.40	27.69	4.62
A25	172.62	5.00	37.54	5.30	39.79	6.00
A26	173.88	5.60	41.74	5.90	43.98	5.36
B25	179.55	6.20	37.81	6.55	39.94	5.64
B26	178.50	5.30	38.48	5.62	40.68	5.71
C25	170.80	5.30	40.22	5.58	42.35	5.28
C26	172.90	5.50	41.23	5.80	43.48	5.45
D25	175.00	5.60	41.47	5.90	43.69	5.36
D26	161.28	5.20	41.78	5.50	44.18	5.76
E25	175.26	4.80	35.50	5.05	37.35	5.21
E26	169.66	4.80	36.67	5.05	38.58	5.21
A27	172.50	6.80	51.09	7.20	54.09	5.88
A28	179.90	6.85	49.35	7.20	51.87	5.11
B27	172.20	6.20	46.66	6.55	49.29	5.64
B28	175.46	6.30	46.53	6.62	48.89	5.07
C27	165.60	6.80	51.65	7.20	54.69	5.88
C28	169.40	6.20	47.43	6.52	49.88	5.16
D27	162.25	6.10	48.72	6.42	51.32	5.33
D28	157.32	6.20	51.08	6.55	53.96	5.64
E27	137.16	6.50	56.69	6.30	59.52	5.00
E28	154.29	6.80	57.12	7.15	60.06	5.14
A29	165.41	4.45	34.87	4.70	36.83	5.61
A30	165.60	4.20	32.87	4.40	34.59	5.23
B29	168.19	4.50	34.68	4.73	36.36	5.11
B30	165.60	4.20	32.87	4.42	34.59	5.23
C29	158.92	3.50	28.54	3.68	30.00	5.14
C30	168.19	4.30	33.13	4.55	35.05	5.81
D29	164.02	3.50	27.66	3.70	29.23	5.71
D30	165.41	3.95	30.95	4.15	32.52	5.06
E29	178.02	3.75	27.30	3.95	28.76	5.33
E30	165.60	3.50	27.39	3.70	28.95	5.71
A31	161.24	4.20	33.76	4.45	35.77	5.95
A32	160.08	3.70	29.96	3.90	31.58	5.41
B31	161.24	3.90	31.35	4.10	32.96	5.13
B32	162.63	4.00	31.88	4.20	33.47	5.00
C31	162.63	3.78	30.12	4.00	31.87	5.82
C32	162.63	3.80	30.28	4.00	31.87	5.26
D31	162.40	3.60	28.73	3.80	30.31	5.55
D32	162.63	3.50	27.89	3.70	29.48	5.71

Table 14 - Continued

Sample	Inches^2	Untreated Web Actual Wt. (grams)	Untreated Web Equivalent (gm/yd^2)	Treated/Cured Web Actual Wt. (grams)	Treated/Cured Web Equivalent (gm/yd^2)	% Day Add-on
E31	159.85	3.90	31.62	4.10	33.24	5.13
E32	163.80	3.60	28.48	3.80	30.55	5.55
A33	156.80	3.75	30.99	3.95	32.64	5.33
A34	156.80	3.80	31.41	4.00	33.06	5.26
B33	156.80	3.50	28.93	3.70	30.58	5.71
B34	158.20	3.60	29.49	3.80	31.11	5.55
C33	155.40	3.30	27.52	3.48	29.02	5.45
C34	158.90	3.40	27.73	3.60	29.36	5.88
D33	155.40	3.70	30.86	3.90	32.53	5.41
D34	156.80	3.70	30.58	3.90	32.23	5.41
E33	156.80	3.80	31.41	4.00	33.06	5.26
E34	158.20	3.70	30.31	3.90	31.95	5.41

APPENDIX D

SAMPLES OF DYED BONDED WEBS

FIGURE 7

DYED SAMPLES OF WEBS BONDED WITH 5% BINDER

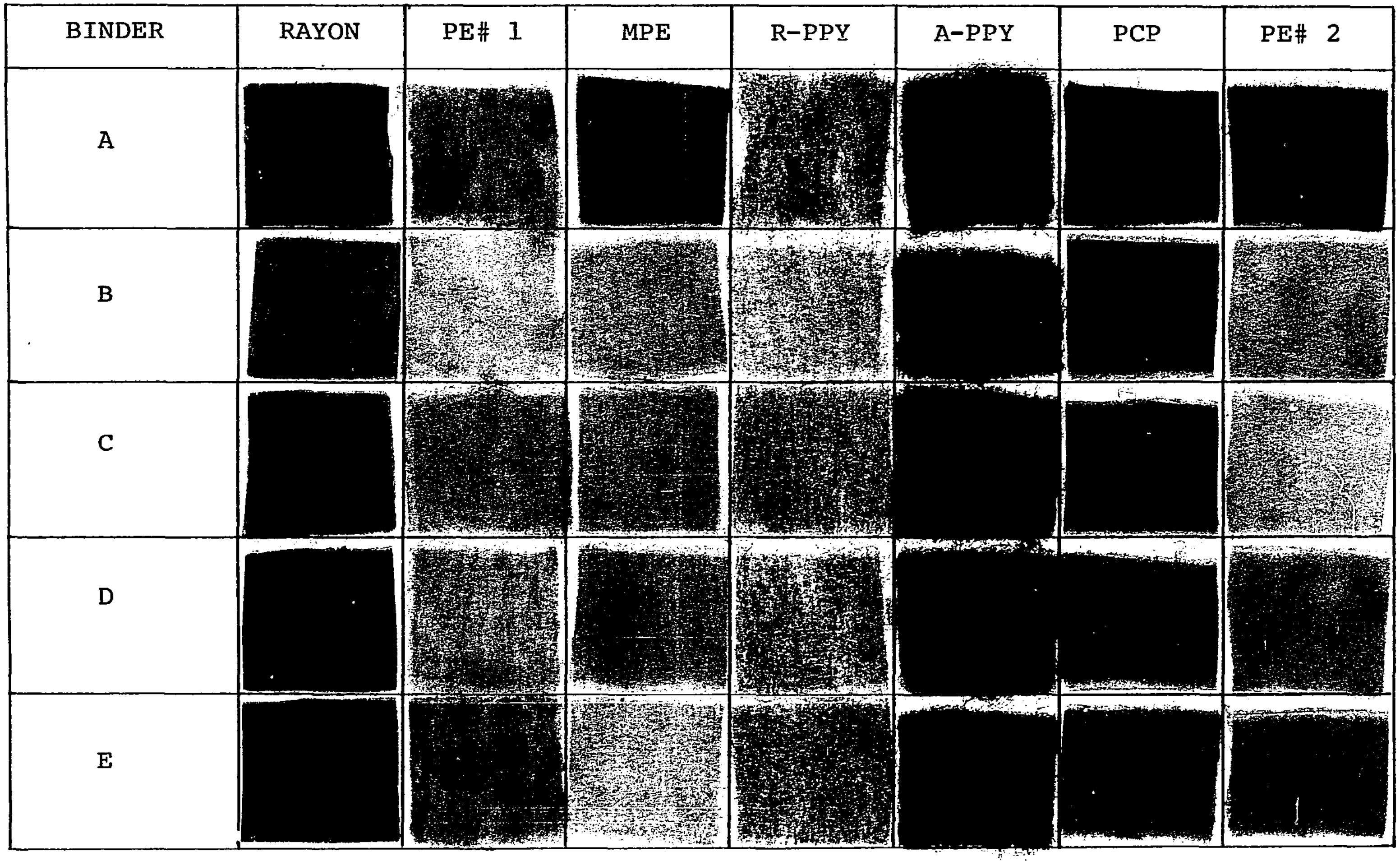

FIGURE 8

DYED SAMPLES OF WEBS BONDED WITH 20% BINDER