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7/25/68

AN INVESTIGATION OF THE MIXING OF COTTON FIBERS BY A PNEUMATIC DELAY DEVICE

A THESIS

Presented to

The Faculty of the Graduate Division

by

Ronald Kelly Ogletree

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in the School of Textile Engineering

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AN INVESTIGATION OF THE MIXING OF COTTON FIBERS

BY A PNEUMATIC DELAY DEVICE

Approved:

Chairman

Date approved by Chairman: June 4, 1970

DEDICATION

To my family, for their patience and understanding.

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SUMMARY

A study was conducted to determine the effectiveness of a specially designed cotton sample blending apparatus. Physical tests and dyed fiber tracer studies were conducted in order to evaluate the blending effectiveness which was achieved by the system.

Specimens of cotton were selected before and after passage through the blending system, and the results of the physical property measurements for each sample lot were compared. Of the physical properties determined, only the bundle strength results indicated conclusively that the sample had been effectively blended. The measurements of fiber fineness and fiber length distribution gave no conclusive results.

The dyed fiber tracer studies indicated that, even under the most stringent conditions, the system provided excellent blending across the width of the sample and through the depth of the sample. Blending in these two dimensions was attributed to the combination of the corner flow and the rotating collection screen. Blending along the length of the sample was not achieved. This was attributed to the high velocities of the particles and the insufficient time delay within the system.

CHAPTER I

INTRODUCTION

Statement of the Problem

The satisfactory blending of relatively small samples of raw cotton has proven over the years to be one of the most perplexing problems facing the textile industry (1). This problem has become increasingly important in the physical testing of samples taken from the bale. It is now known that tests performed on samples taken from different areas of a bale will yield different measures of such properties as strength, length and uniformity ratio (2). Recent studies of American and foreign-grown cotton have indicated some of the variation which is to be expected in each of the above properties (3). Thus, in order to obtain test results which are truly representative of the properties of an entire bale of cotton, it would be desirable to preblend the cotton subsamples before testing.

The development of high speed, automated testing lines has further complicated the problem. These testing systems are capable of performing all of the essential physical tests on a 100 grams bale sample in approximately seven seconds (4). Laboratory sample blending instruments in use at the present time are not only much too slow for such a testing system, but few of them are capable of blending samples of the required size. Also, many of the present blenders alter the physical properties of the samples, either by fiber breakage or by nep formation.

The requirement of a high speed blending instrument coupled with the desirability of minimal fiber damage during blending has led to the possible use of pneumatic systems.

Purpose of the Research

The purpose of this research is to investigate the feasibility of using aerodynamic means to mix relatively small cotton tufts or individual fibers. The blending effectiveness of a pneumatic blending system comprised of a right angle duct, a delay system and a rotating collection screen will be evaluated. Theoretically, the right angle duct would first classify the cotton particles according to their sectional densities. While this would not provide effective blending of the sample, the corner flow would serve as a means of placing the tufts across the width of the sample and through the depth of the sample out of position with respect to their original position in the sample. The delay system should add a time delay factor dependent on the speed and paths of travel of the particles. Thus, the delay system would produce blending of the tufts along the length of the sample. The rotating collection screen should redistribute the particles by collecting the tufts in a random manner from different areas of the sample as they pass through the system. The entire system would theoretically yield a sample which has been blended across its width, through its depth, and along its length (if a sufficient time delay is achieved).

CHAPTER II

REVIEW OF THE LITERATURE

Evaluation of Present Laboratory Sample Blending Instruments

A survey of the literature indicated that preliminary studies have been conducted on the effectiveness of present sample blending instruments. An analysis of available systems was recently completed at the Georgia Institute of Technology (6). Three instruments were evaluated:

1. A mechanical cotton blender marketed by Custom Scientific Instruments, Incorporated (C.S.I.), seen in Figure 1.

2. The Shirley miniature card, seen in Figure 2.

3. A prototype sample blender developed by the Stanford Research Institute (S.R.I.), seen in Figure 3.

The methods used for evaluation of blending effectiveness were:

1. The use of dyed fiber tracers for visual examination of coloration mixture.

2. The use of differential dyeing on samples of mature and immature fibers after blending, and visually inspecting for coloration mixture (ASTM Designation: D 1464-63).

3. Blending samples of high fineness with samples of low fineness.

The fineness of the blended sample was compared to the arithmetic average of the two unblended samples.

Visual examination of the blended samples obtained from the first

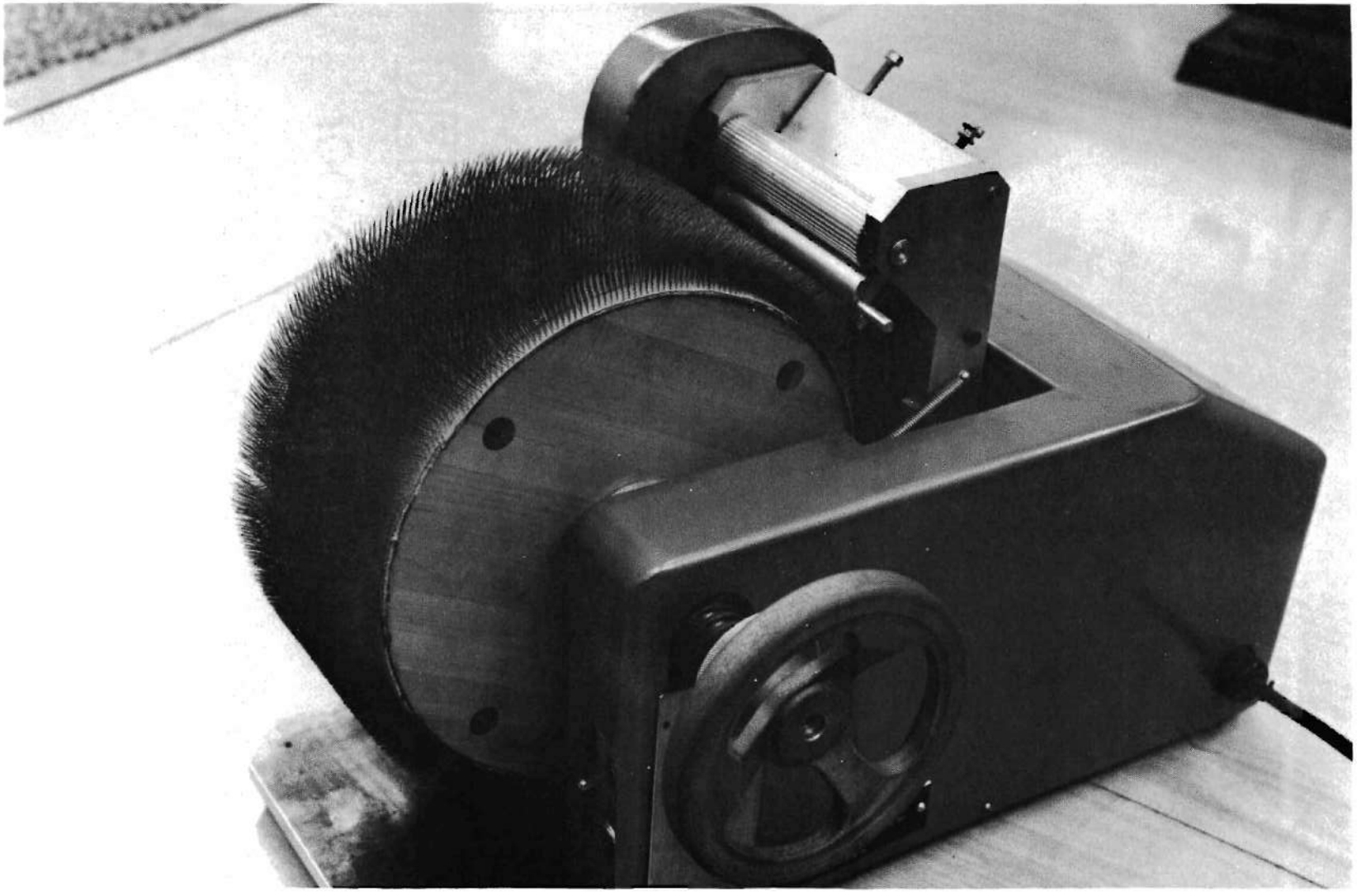

Figure 1. Custom Scientific Instruments Mechanical Cotton Sample Blender

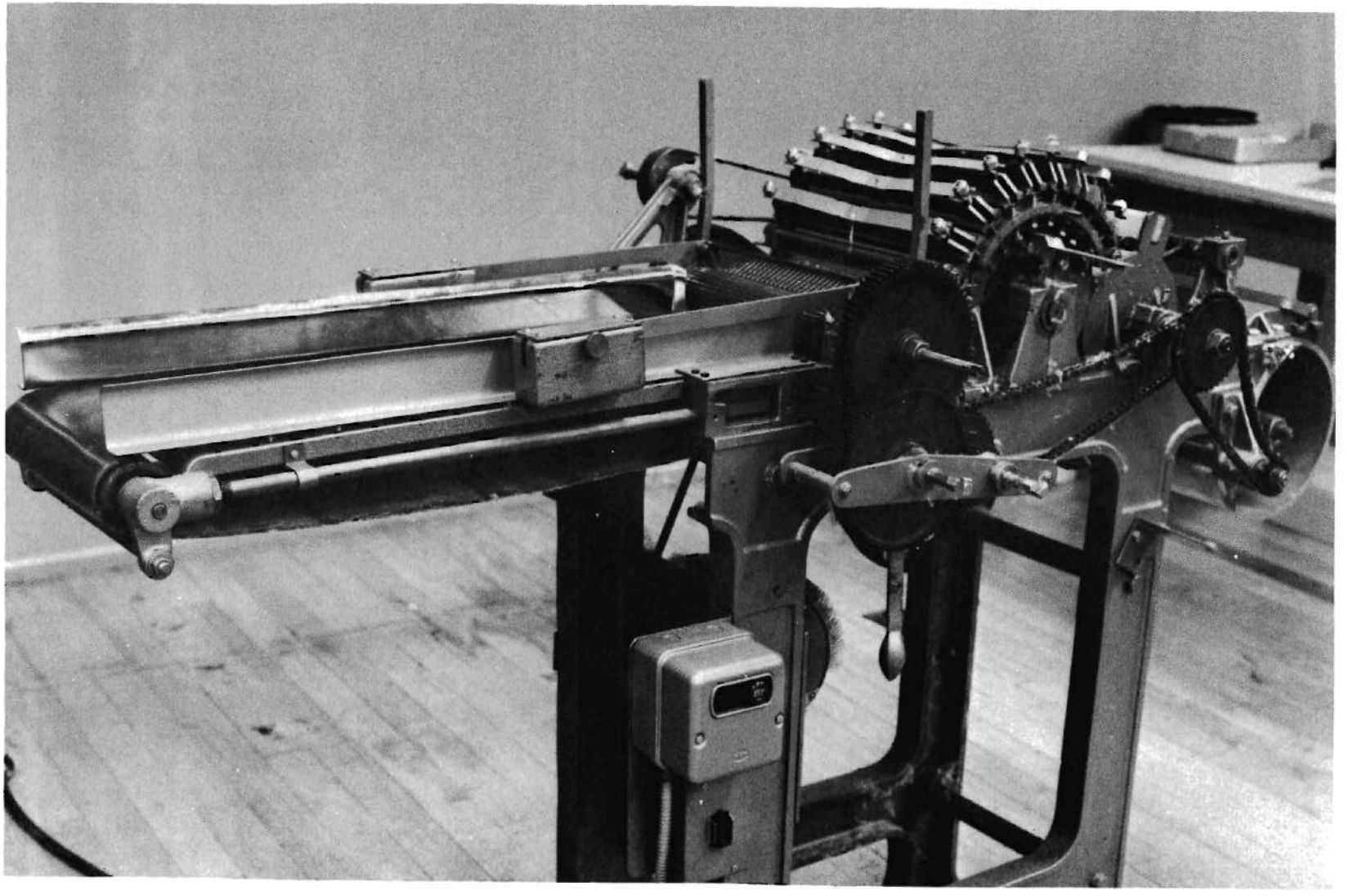

Figure 2. Shirley Miniature Card

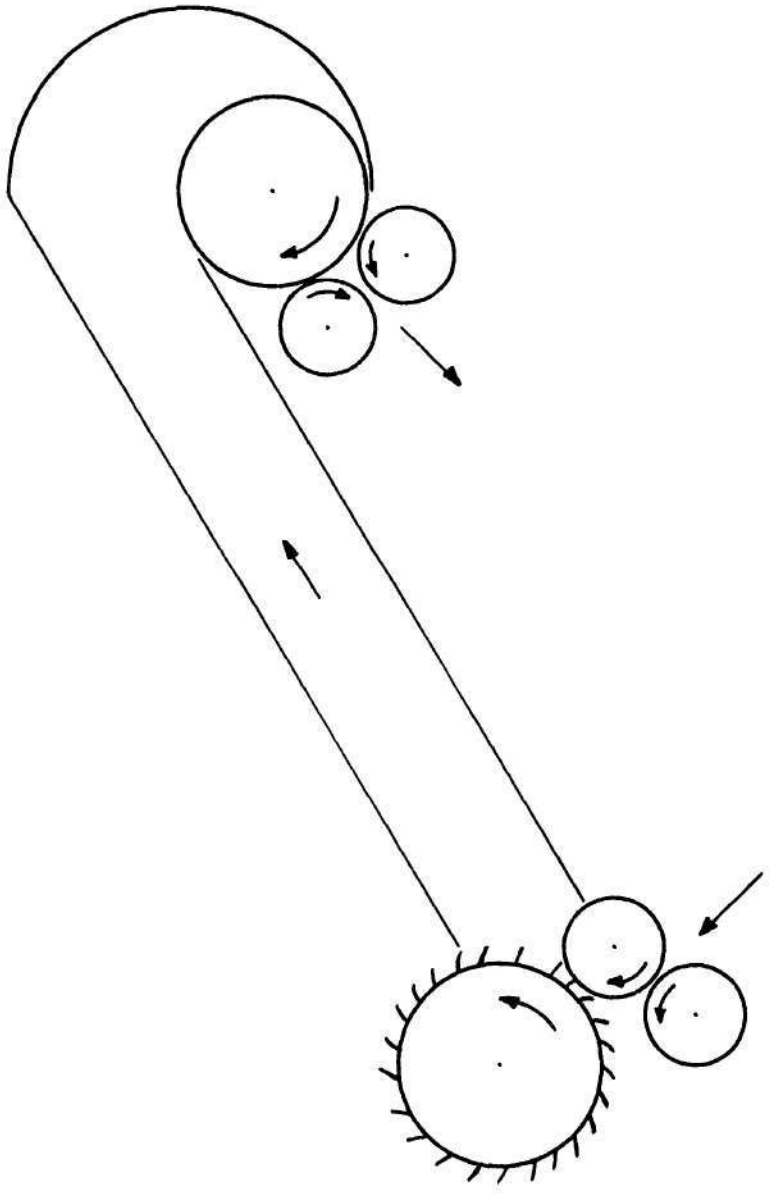

Figure 3. Schematic Diagram of the Stanford Research Institute Cotton Sample Blender

test method revealed that all three instruments gave relatively poor distribution of the dyed fiber tracers. The blending cylinder of the C.S.I. blender did not remove sufficiently small tufts of fibers to allow good coloration mixture. The Shirley miniature card provided a coloration mixture superior to the other two instruments, but there was considerable fiber damage in the process. The S.R.I. prototype blender produced a slightly better blend than did the C.S.I. blender, and fiber damage was relatively low. The nylon brush licker-in on the S.R.I. blender produced a considerably smaller average tuft size than the blending cylinder of the C.S.I. blender. The major difference in coloration mixture was attributed to this fact.

Physical tests were also performed on the samples obtained in the dyed fiber tracer test. The measurements of length distribution, uniformity ratio and fiber bundle strength are given in Table 1.

Table 1. Results of Method One Blending – Evaluation of Present Sample Blenders

	50% Span Length	2.5% Span Length	Uniformity Ratio	Tenacity (Grams per Tex)
C.S.I. Blender				
Before Blending	.49	1.09	45.0	46.7
After Blending	.49	1.12	44.0	45.5
S.R.I. Blender				
Before Blending	.49	1.09	45.0	46.7
After Blending	.49	1.07	46.0	44.9
Shirley Card				
Before Blending	.49	1.09	45.0	46.7
After Blending	.49	1.05	46.0	45.5

Using the differential dyeing test method, the C.S.I. blender demonstrated poor blending of mature and immature fibers. Distinct tufts of both mature and immature fibers were clearly present in the blended sample. As in the first method, the Shirley miniature card produced superior color distribution of red and green fibers throughout the sample after blending. Again, the S.R.I. blender provided better blending than the C.S.I. blender, but was inferior to the Shirley card.

In the third method of evaluation, equal weights of 6.10 micrograms per inch cotton and 2.65 micrograms per inch cotton were blended together. A perfect blend would therefore yield a sample with a fineness of 4.37 micrograms per inch. There was very little difference in the performance of the three instruments using this method of evaluation. Results of this test are shown in Table 2.

Table 2. Fineness Readings Using Test Method Three – Evaluation of Present Sample Blenders

Blending Instrument	Fineness (Micrograms per Inch)
C.S.I. Blender	4.00
S.R.I. Blender	3.98
Shirley Card	3.95

Note: These readings are compared to the 4.37 arithmetic average obtained by mixing equal weights of 6.10 micrograms per inch cotton with 2.65 micrograms per inch cotton.

All three instruments were shown to have certain disadvantages

which would make their use with an automated testing line undesirable. The Custom Scientific Instruments blender exhibited poor blending effectiveness and was very slow in operation. The Shirley miniature card was also much too slow and inflicted considerable fiber damage during blending. The Stanford Research Institute prototype was not capable of blending sufficiently large samples and provided only fair blending.

Other Methods of Blending

Several other methods for blending cotton samples on the laboratory scale have been investigated to a limited extent (7). Some of these methods are merely modifications of existing systems, but there are several new methods under investigation.

One method (8) consisted of utilizing high-velocity, compressed-air jets. Difficulty has arisen in the application of such a system due to the tendency of cotton fibers to tangle when blown through pneumatic systems. The failure of this method was evidently due to the turbulence necessary to break up the sample and redistribute the tufts in a blended form. Attempts at changing various components of the system failed to reduce the harmful effects on the cotton. Neither the addition of flow restrictions nor the changing of the jet angles prevented the tangling of the fibers in the air stream.

Another method (9) of blending attempted to separate and redistribute the tufts of fibers by electrostatic forces. This method also was not satisfactory. Even when a potential of 30,000 volts was applied to a cotton sample placed between two parallel plates, the electrostatic forces developed were not sufficient to give an effective blend.

Still another method (10) made use of a centrifuge to blend the cotton sample. The sample was placed in rotating holders in a centrifuge and turned at speeds up to 3600 revolutions per minute on a radius of ten inches. The fibers were allowed to penetrate through a system of obstructions and collect on the walls of the centrifuge. Using this system, some individual fibers were collected, but apparently the forces developed were not sufficient to effectively separate the cotton tufts from the original mass and blend them.

The unsuccessful methods of blending mentioned above serve to emphasize the difficulty of separating and blending relatively small tufts of fibers from bale samples. While the investigations have not led to an efficient blending system, much has been learned about the behavior of cotton tufts and fibers under differing flow conditions.

The Pneumatic Conveyance of Cotton Tufts

The theory and application of the conveyance of fibrous materials have received considerable attention during the past several years. This is probably due to the increased use of pneumatic conveyors for cotton processes in American and foreign textile mills (11). This portion of the literature survey was limited to the theory and observations directed primarily toward studies of the transport of cotton tufts in air flows. Special emphasis was placed on the flow parameters of cotton in horizontal ducts.

Potapov (12) stated that two important parameters for the pneumatic transport of cotton in horizontal ducts are the starting velocity and the soaring speed. He defined the starting velocity as the minimum air ve-

locity necessary to impart motion to a fibrous material. The soaring speed was defined as the air velocity at which a fibrous particle will neither rise nor fall in a vertical air current. At this flow velocity, the weight of the particle is exactly offset by the aerodynamic force of the air stream acting on the particle.

Potapov (13), Ermolaev (14), and Morozov and Shal'kin (15) concluded that, while the starting velocity of a particle is relatively constant for a given material, the soaring speed is dependent on many factors. Ermolaev proposed that the soaring speed is dependent on the density, size, shape and surface conditions of a particle. He also reported that the Reynold's number of the flow and the density of the air contributed to the soaring speed of the particle. Morozov and Shal'kin theorized that the complexity of the soaring speed corresponded with the forces of resistance (drag) experienced by a particle in a flow field. Potapov concluded that, in the flow of air around and through the highly developed surfaces of a cotton tuft, a friction force developed which was the principal vector of resistance to the air current.

Potapov (16) offered a method of determining the soaring speed for a cotton particle. He proposed that the product of the soaring speed of a particle and the cross-sectional area of that particle presented to the air stream was constant for a given particle of a specified weight.

$$V_s \times F_{mid} = A$$

where:

V_s = the soaring speed of the particle (meters per second),

F_{mid} = the cross-sectional area of the particle presented to the

air stream (square centimeters),

A = a constant for particles of the same material and of the same weight.

For cotton, Potapov stated that the value of "A" was:

$$A = \sqrt{19360 \times W}$$

where:

W = the weight of the particle in grams.

Potapov (17) theorized that, while the soaring speed was dependent on many variables, the starting velocity was not influenced by the degree of looseness, the weight, or the concentration of cotton particles in the duct. He proposed that the starting velocity was dependent only on the nature of the material in question. He also stated that the starting velocity was not dependent to a marked extent on the duct diameter. For cotton, the starting velocity was measured to be 3.60 meters per second.

Potapov (18) and Morozov and Shal'kin (19) postulated that a linear relationship existed between the soaring speed and the starting velocity for a given fibrous material.

$$V_m = V_{st} - V_s\sqrt{f}$$

where:

V_m = the velocity of the particle (meters per second),

V_{st} = the starting velocity of the particle (meters per second),

V_s = the soaring speed of the particle (meters per second),

f = the coefficient of friction of the particle with the surface of the duct.

In actual experiments conducted with raw cotton, Dyuzhev (20) observed that, in horizontal ducts in which the air velocity was at a minimum, the bulk of the cotton was not suspended in the air stream but slid along the bottom of the duct. Only individual tufts were observed to separate from the mass and leap along the duct. These observations were confirmed by Kalinushkin (21) and Morozov and Shal'kin (22). Kalinushkin concluded that a fibrous material probably does not exhibit helical motion due to its large, highly developed surface area, soaring properties, and low density which resist the effect of centrifugal forces and gravity as against the forces of the air current. Therefore, the particles were theorized to fly in a straight line parallel to the axis of the duct.

Feldman (23) reported that the aerodynamic force acting on light bodies, such as cotton particles, varied in proportion to the square of their linear dimensions and in proportion to the velocity difference between the body and the air. He stated that the inertial resistance to such a force was proportional to the weight of the particle. It was concluded that a small current of air was sufficient to carry along the particles and they responded to changes in velocity of the air flow very quickly. Mayer and Feldman (24) illustrated this by stating that an individual fiber would attain the speed of the surrounding flow field in approximately .006 second. Feldman (25) noted, however, that regardless of how rapidly the particles come into equilibrium with the flow field, the lag would always be finite and the amount of lag would depend

both on the lightness of the particle and the rate at which the direction or speed of the flow field changed.

Feldman (26) proposed that the aerodynamic force acting on the particle was in the direction of the relative wind. He assumed that the aerodynamic force had no components perpendicular to the velocity of the air relative to the body. He justified this assumption by stating that, at the low Reynold's numbers pertaining to this flow, the aerodynamic forces in the direction of the relative wind were much larger than the forces normal to the relative wind.

The Flow of Fibrous Particles Around Corners

Genovese and Feldman (27) conducted an analytical investigation of the dynamic behavior of cotton particles in corner flows. The study was largely theoretical and unsupported by experimental results. The problem was idealized in order to apply the well-defined laws of the dynamics of particles in potential flows.

In the study, it was reported that the weight-shape characteristics of particles were very influential on the behavior of cotton tufts in corner flows. The weight-to-area ratio, or sectional density, of cotton fibers or tufts is very small and tends to keep the particles in equilibrium with the air flow. Due to the lightness and certain other physical properties of cotton tufts and fibers, gravity forces were considered to be negligible.

Genovese and Feldman also proposed that a relationship existed between the input positions of the tufts and their respective output positions. The input position was defined as a position at the entrance to the duct at which the particle begins its path of travel through the

system. The output position was defined as a position at the outlet of the duct, downstream of the corner, at which the particle concludes its path of travel through the system. Both the input and output positions were measured normally to the inner wall of the right angle duct. For a given input position, the output position of a particle with a relatively larger sectional density would be greater than the output position of a particle of lower sectional density. It was also indicated that the deviation from the streamlines of the flow would be greater for particles of greater sectional density after they pass downstream of the corner. Also, it was shown that, for particles of a given sectional density, the fiber or tufts closest to the inner wall of the duct would suffer the greatest displacement from the streamline paths of the flow.

CHAPTER III

MATERIALS AND EQUIPMENT

Raw Materials

The raw material for the physical testing portion of the investigation consisted of card sliver of New Mexican cotton with a staple length of 1.25 inches.* A picker lap was processed in the Fiber Processing Laboratory by Mr. Ramsey C. Freeman. A sliver which weighed 63 grains per yard was produced by the cotton card.

For the dyed fiber tracer portion of the investigation, raw cotton stock was used. Subsamples of the raw stock were dyed for use as fiber tracers. The procedure for dyeing the cotton is given in Chapter IV.

Opener for Physical Testing Portion of the Investigation

In order to feed relatively small cotton tufts or individual fibers into the blending system, an efficient opening device was considered essential. After considerable investigation (28) and consultation (29), it was decided that a draw frame would afford a suitable opening device with minimum fiber damage.

The draw frame chosen was the Shirley miniature draw frame, Figures 4 and 5. This machine is a single delivery frame which can be fed by a card sliver or a drum creel sliver lap. A card sliver was used in

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*As measured by the Fiber Evaluation Laboratory, A. French Textile School, Georgia Institute of Technology.

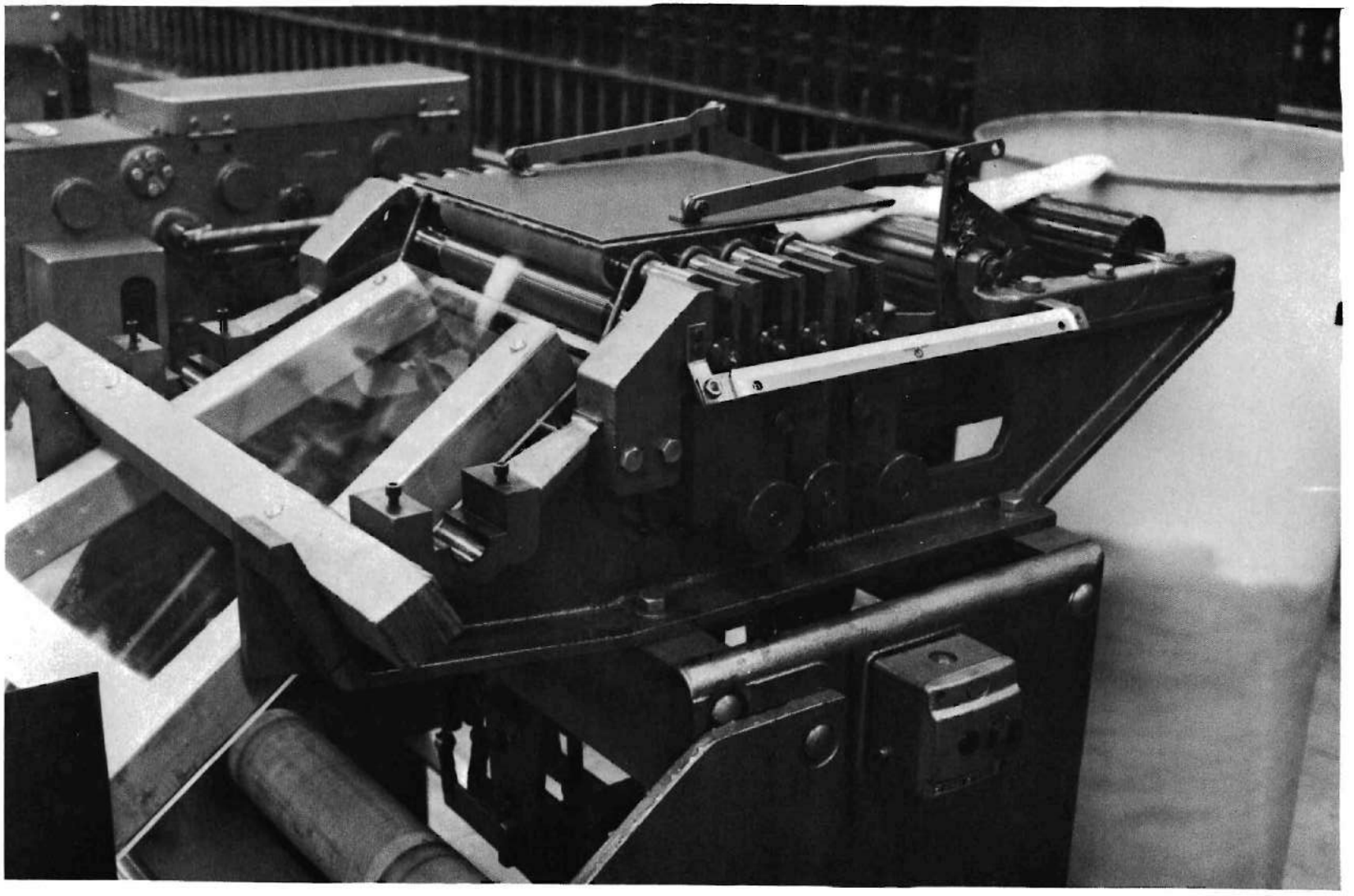

Figure 4. Shirley Miniature Draw Frame

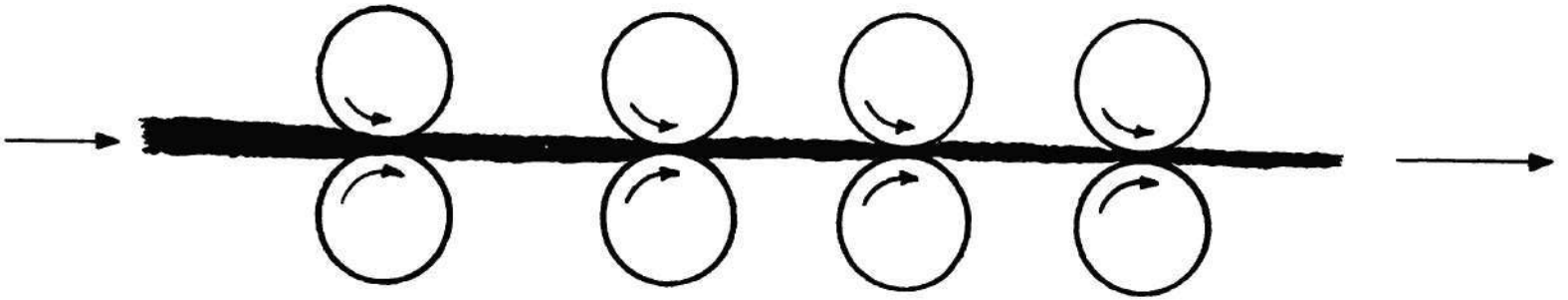

Figure 5. Schematic Diagram of a Four-Over-Four Roll, Two-Zone Drafting Arrangement

this investigation. The sliver passes through a four-roller, two-zone drafting arrangement equipped with needle bearing, spring-weighted top rollers and Shirley fluted bottom rollers. A weight relieving motion is fitted to the machine. The draw frame utilizes flat reciprocating top and bottom clearers. All drives are taken from a fixed-center gear box through universal couplings.

Manufacturer and general processing information for the draw frame are given in Table 9 of the Appendix (30).

Opener for Dyed Fiber Tracer Portion of the Investigation

In order to feed portions of dyed and undyed cotton into the blending system for the dyed fiber tracer studies, a specially constructed opener was utilized, Figure 6. Basically the opener consisted of a set of feed rolls which introduce the sample to a high-speed, nylon brush licker-in. As the stock emerges from the feed rolls, the licker-in plucks small tufts of cotton from the sample mass. After the tufts are opened by the licker-in, the air current flowing through the blending system pulls the tufts off the licker-in and into the blending system.

Specifications for the opener are given in Table 10 of the Appendix.

Blending System

For the investigation of blending cotton samples by a pneumatic delay line, a specially designed wind tunnel was constructed, Figure 7. The base of the duct was made from a plywood sheet three-fourths inch thick. The base was painted and sanded with fine steel wool to insure reasonable smoothness. The sides of the tunnel were rolled from 16 gauge

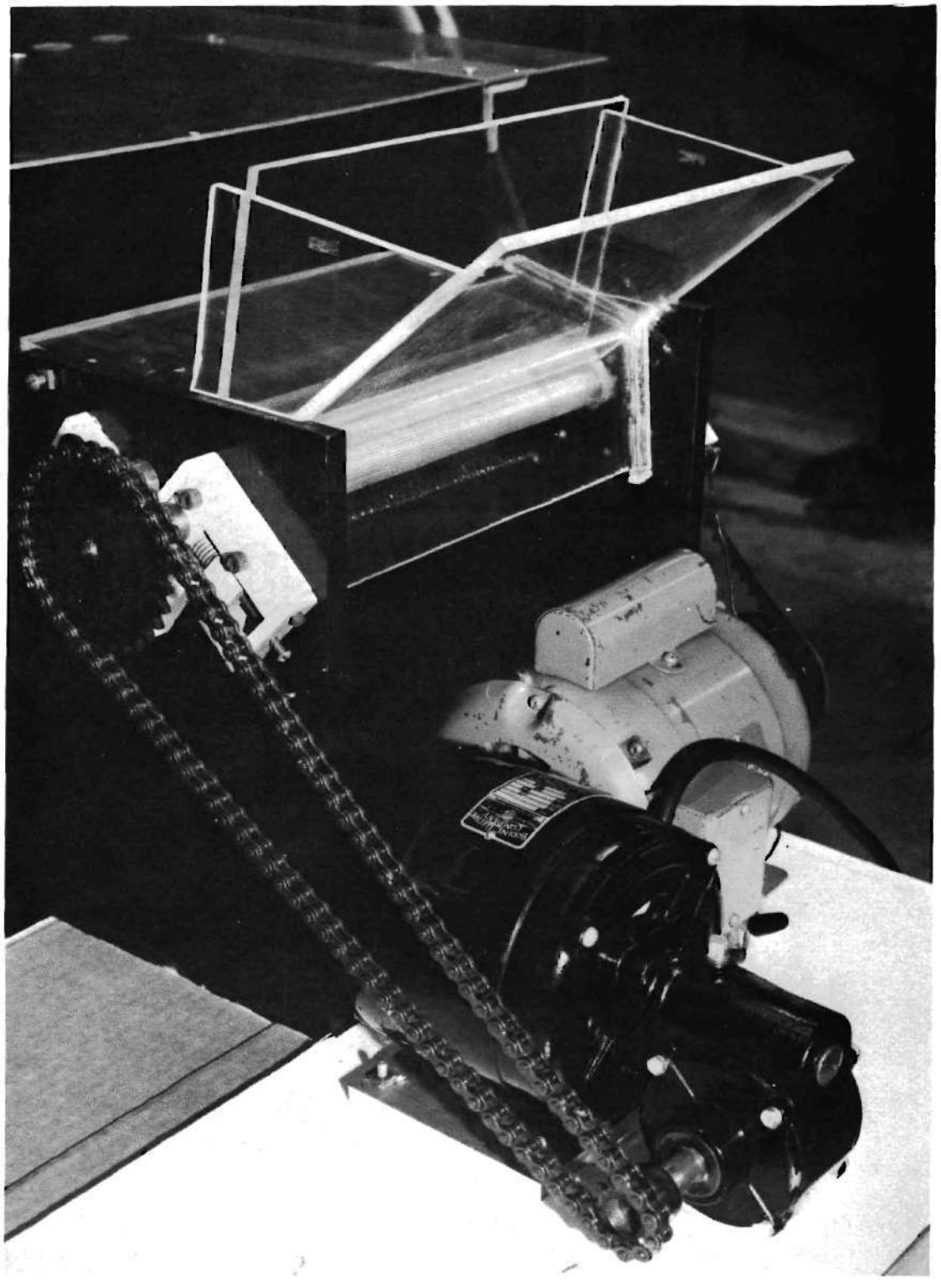

Figure 6. Specially Constructed Opener Used in Dyed Fiber Tracer Studies

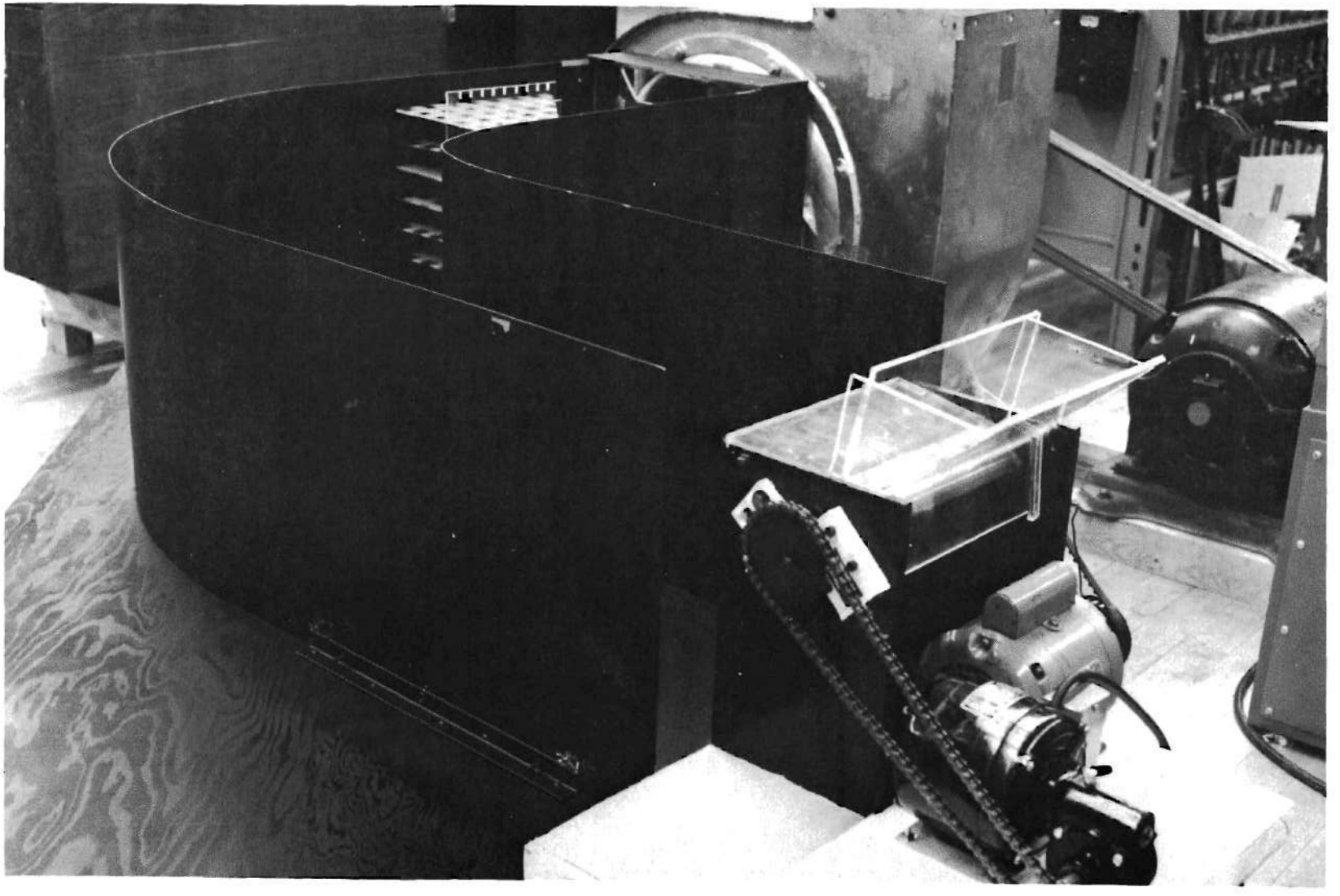

Figure 7. Over-all View of the Specially Constructed Blending Apparatus (with Top Removed)

sheet metal. The two metal sides were placed on the plywood base and secured with angle iron brackets. The top consisted of two Plexiglas sheets one-eighth inch thick. The two portions of the top were hinged together to allow access to the outlet branch of the duct.

A pneumatic delay system was constructed from Plexiglas sheets, Figure 8. The system consisted of a "honeycomb" arrangement with varying length compartments. The horizontal components of the "honeycomb" were triangular shaped to achieve the delay desired. The delay system divided the cross section of the main duct into 27 smaller ducts.

A circular, rotating collection screen driven by a small electric motor was placed behind the outlet of the delay system, Figure 9. The circular screen frame was cut from plywood and covered with a loose weave (32 x 32) nylon fabric.

A large centrifugal blower driven by a ten horsepower electric motor was positioned at the outlet branch of the duct to provide the vacuum source. The blower provided a flow rate of 27 cubic feet per second within the system.

Pertinent dimensions of the blending system are given in Figure 10.

Fiber Property Measurement Apparatus

Standard, commercially available instruments were used in the evaluation of the physical properties of the cotton specimens. The properties of fineness, bundle strength and length distribution were measured by the following instruments:

1. The Pressley Fiber Bundle Strength Tester
2. The Fibronaire Fiber Fineness Tester

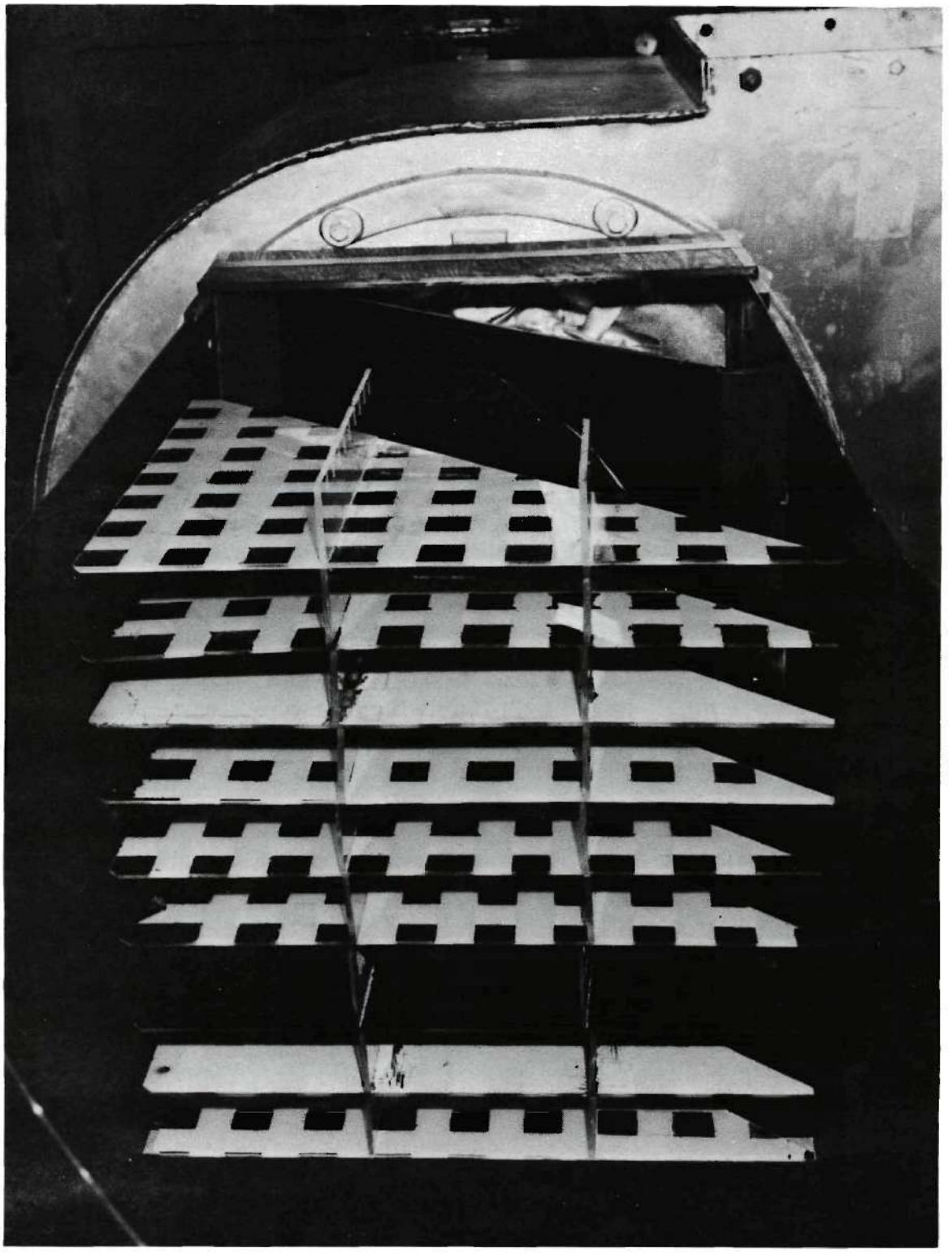

Figure 8. The Delay Portion of the Constructed Blending Apparatus

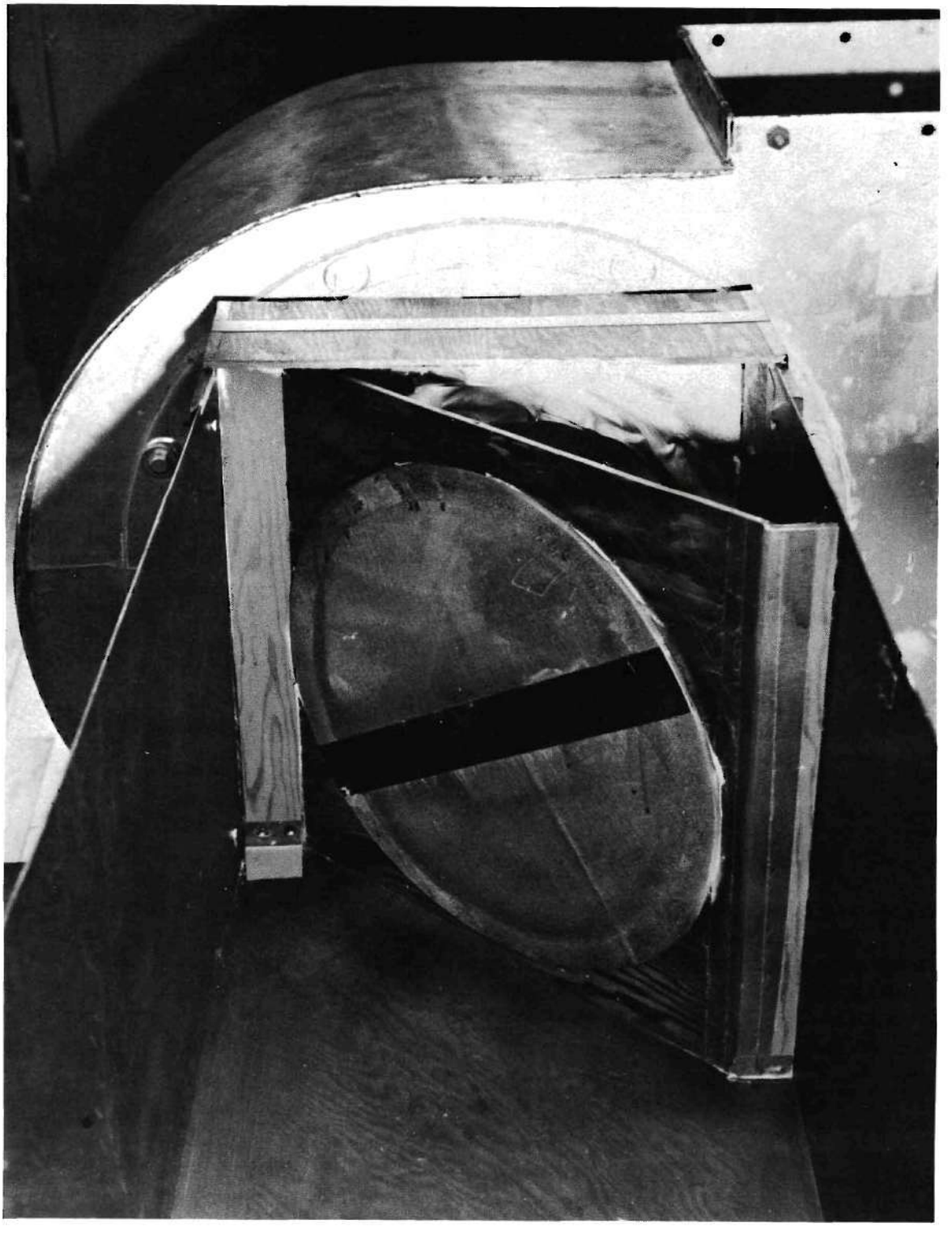

Figure 9. The Rotating Collection Screen of the Constructed Blending Apparatus

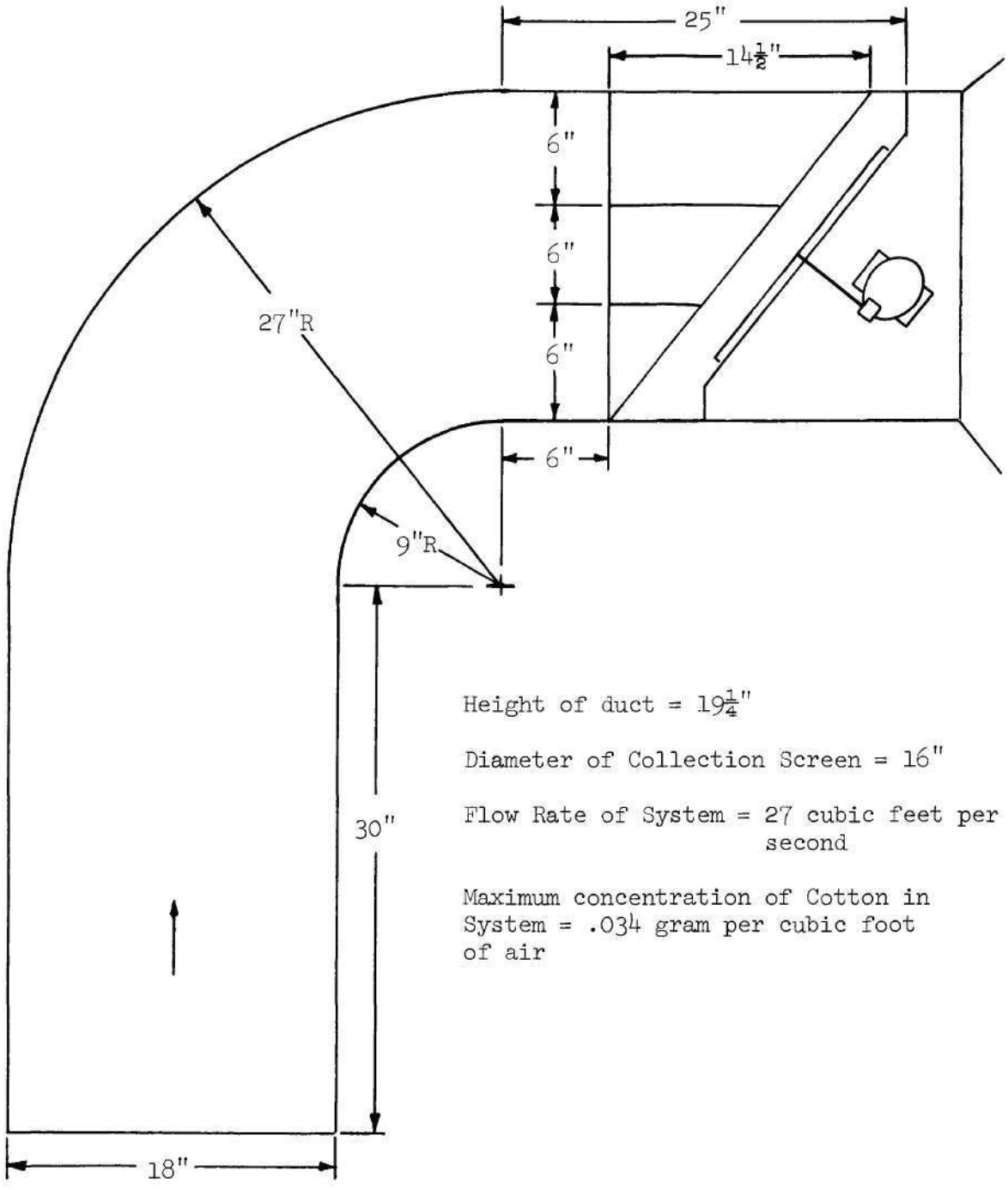

Figure 10. Schematic Diagram of the Specially Constructed Blending System

3. The Digital Fibrograph, Model 230-A (with Fibrosampler).

These instruments are pictured in Figures 11 through 14.

Dyed Fiber Tracer Tests

Blending effectiveness of the apparatus was examined by the use of dyed fiber tracers mixed with the undyed cotton. The tests involved feeding dyed and undyed cotton into the blending system in several different manners and visually inspecting the composite sample for coloration mixture. The procedure for dyeing the cotton stock and test methods are given in Chapter IV. Specifications of the dye bath are given in Table 11 of the Appendix.

Figure 11. Pressley Fiber Bundle Strength Tester

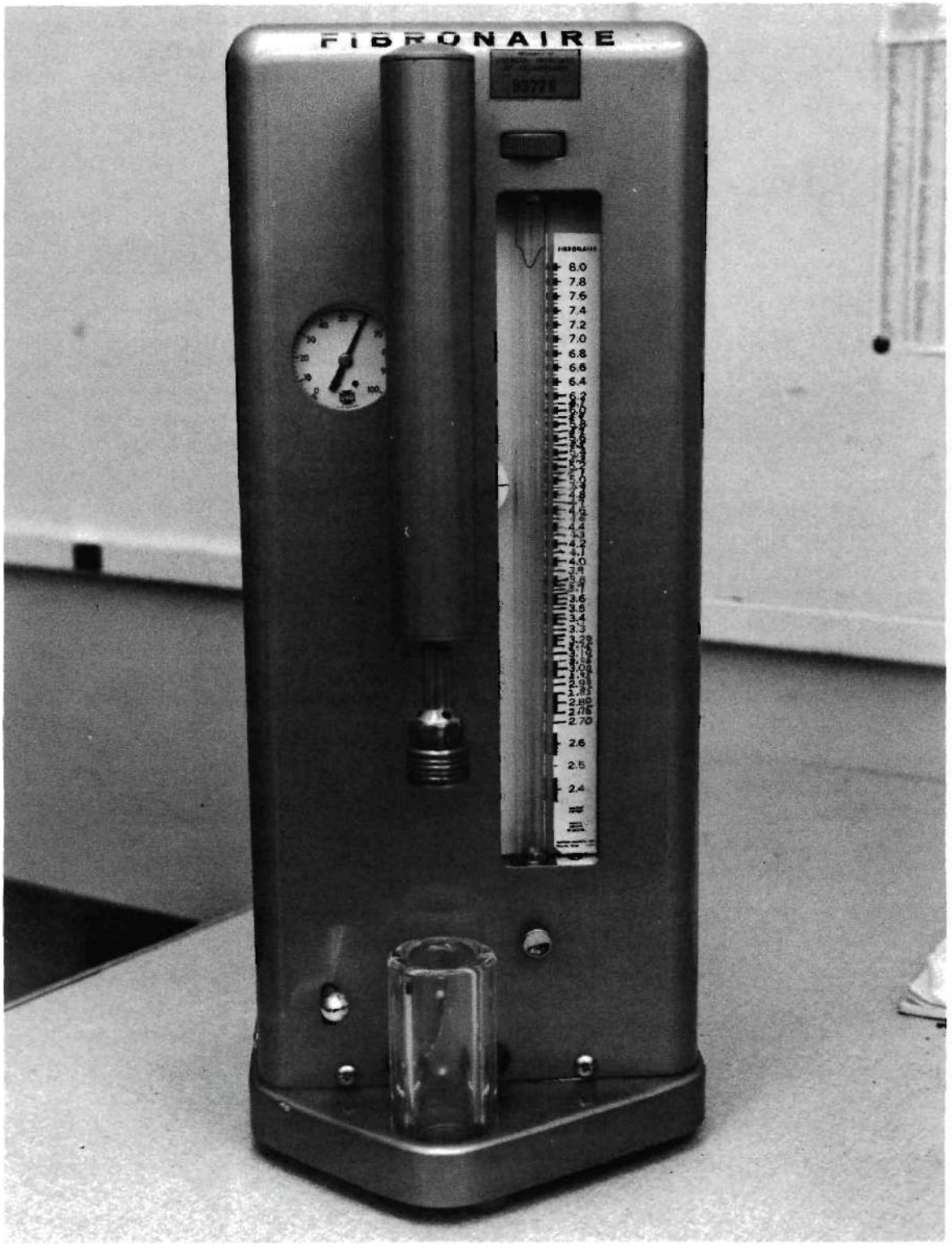

Figure 12. Fibronaire Fiber Fineness Tester

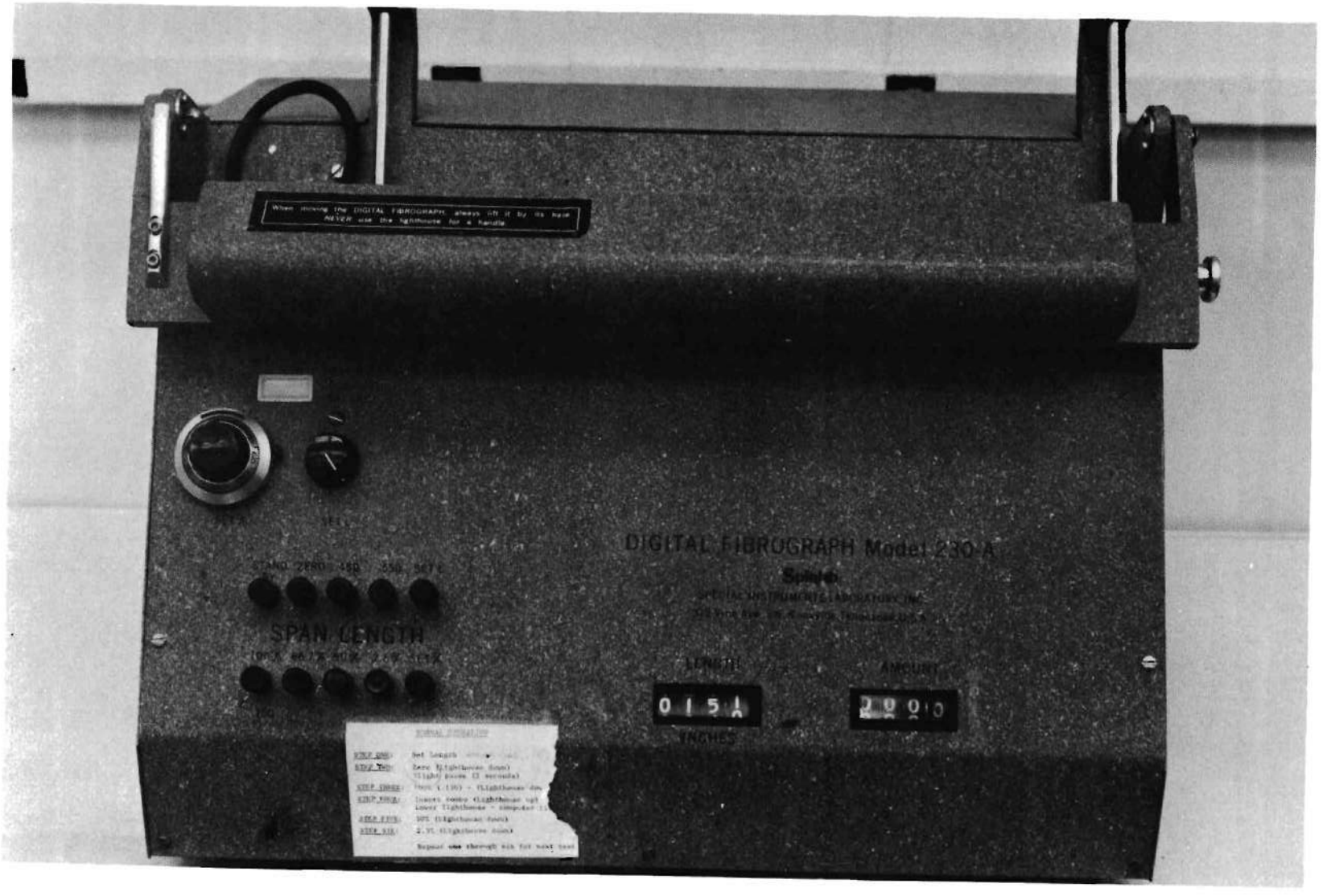

Figure 13. Digital Fibrograph, Model 230-A

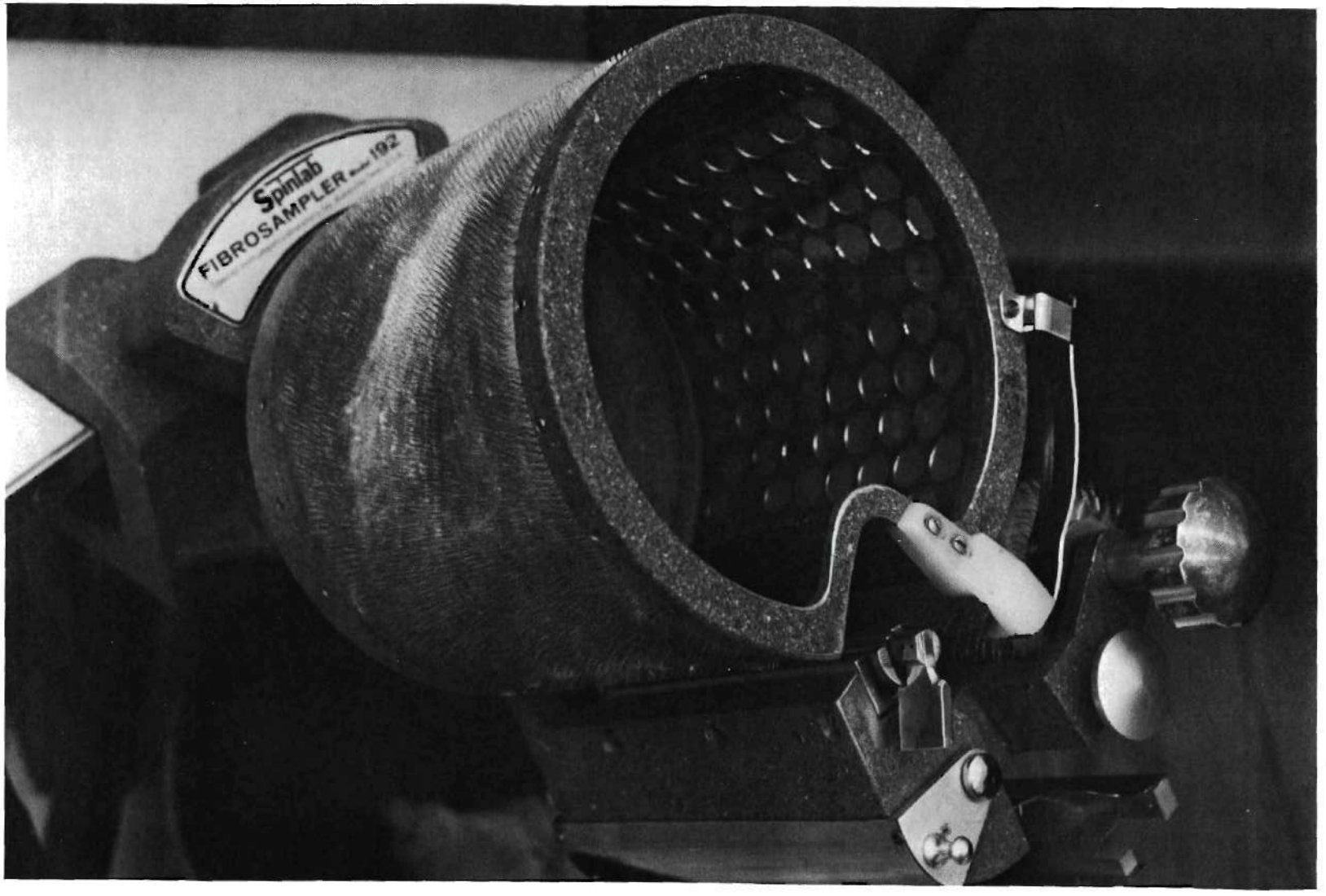

Figure 14. Fibrosampler, Model 192

CHAPTER IV

PROCEDURE

Sampling

Small samples of cotton stock were chosen for testing before and after blending. In order to minimize any effect which the draw frame might have on the properties of the cotton, samples were selected after the sliver had been processed through the draw frame. For determining the properties of the cotton before blending, the cotton was collected in a sliver can after emergence from the draw frame. For determination of fiber properties after blending, the cotton was collected on the rotating screen of the blending system and then doffed manually. For the dyed fiber tracer studies, raw stock was used instead of sliver, and the draw frame was not utilized as a feed device. The specially constructed opener described in Chapter III was used to feed the raw stock into the system for the dyed fiber tracer studies.

Draw Frame Preparation

Before the card sliver was processed through the Shirley miniature draw frame, the drafting rollers were cleaned according to manufacturer's recommendations (31). Oil traces were removed from the fluted rollers and the bright metal parts with a soft cloth and paraffin. The rolls were then carefully dried and covered with a light coat of French chalk. Then the rollers were brushed with a stiff bristle brush and polished with soft waste.

Blending Procedure

A Shirley miniature draw frame was utilized to feed the sliver into the blending apparatus. As the thin web of fibers emerged from the front rollers of the draw frame, the fibers were transferred to the main duct through a small pneumatic duct. The fibers were allowed to travel through the blending system and collect on the rotating screen. After approximately 25 grams of cotton were fed into the system in this manner, the system was turned off and the sample was removed from the screen manually.

Measurement Procedures

The specimens collected both before and after blending were measured for the properties of bundle strength, fineness and length distribution. All measurements were made in the Fiber Evaluation Laboratory at the A. French Textile School.

Fiber Bundle Strength

Fiber bundle strength was measured using the Pressley tester. All measurements were made at zero gauge length. Before evaluation of any of the samples, the instrument was examined to insure that it was in proper operating order according to the operating manual (32).

The leather pads on the clamps were checked for scratches and the clamps were placed in a vise. The clamps were then opened. A small composite sample was formed by taking several small pinches of cotton from the larger sample. A small bundle was taken from the prepared composite sample and the fibers were paralleled by combing. A fiber band or ribbon approximately one-fourth inch wide was placed in the open jaws of

the clamps so that an equal length of fibers extended on each side. The top clamps were lowered and locked into place. The jaws were removed from the vise and protruding fibers were trimmed from the edge of the jaws with a special knife.

Next, the jaws containing the fibers were placed into the slots at the right end of the beam (see Figure 11) after the beam had been raised. The beam weight was released by raising the locking level. The clamps were removed from the instrument and placed in the vise. The top jaws were unlocked and the broken fibers removed with tweezers and weighed in a torsion balance to the nearest 0.1 milligram.

The tenacity of the specimens at zero gauge length was calculated using the following formulas:

$$\text{Pressley Index} = \frac{\text{Breaking Load in Pounds}}{\text{Bundle Weight in Milligrams}}$$

$$\text{Tenacity (Grams per Tex)} = \text{Pressley Index} \times 5.4$$

Fiber Fineness

Fiber fineness was evaluated using the Fibronaire. The Fibronaire was selected due to its acceptance by the Fiber Evaluation Laboratory at the A. French Textile School.

The instrument was calibrated in compliance with the manufacturer's recommendations before any samples were evaluated. From the samples collected, test specimens of 50 grains each were weighed on a Precisionaire balance. Each specimen was in turn placed in the compression chamber of the Fibronaire. The compression plunger was then lowered into the com-

pression chamber by depressing the control lever. The plunger compressed the specimen into a cylindrical form one inch in diameter and one inch long. After compression, an air pressure of six pounds per square inch was passed through the fibers in the chamber. A fineness reading in micrograms per inch was taken from the calibrated scale on the instrument. After the fineness index was recorded, the control lever was raised, the compression plunger lifted, and the specimen was ejected from the compression chamber by a pulse of compressed air from below the specimen.

Length Distribution

The length distribution of the samples was measured on the Digital Fibrograph, Model 230-A. Calibration of the instrument was performed according to manufacturer's specifications before any samples were evaluated (33).

Fiber beards were prepared from the samples by use of the Fibrosampler. Two combs or beards were prepared for each sample and placed in the comb carrier of the Fibrograph. Trash and non-uniform thicknesses were minimized by brushing the fibers into parallel rows. The light source of the Fibrograph was moved to the 100 percent position and a reading was taken for the 100 percent amount. If this amount fell outside the range of 1400 to 1800 fibers, the beards were discarded and additional beards were prepared. The 100 percent amount relates the number of fibers present in the beards. With acceptable fiber combs in position, the 66.7 percent button was depressed and the span length was read from the counter. Then the 50 percent button was depressed and the corresponding span length was recorded. Finally the 2.5 percent button was depressed and this span length was recorded.

Using the 2.5 percent and 50 percent span lengths, the uniformity ratio was calculated by the following formula:

$$\text{Uniformity Ratio} = \frac{\text{50 percent Span Length}}{\text{2.5 percent Span Length}} \times 100$$

The upper quartile length and mean length for each of the samples were estimated utilizing a graphical solution formulated by Louis and Fiori (34).

Statistical Analysis of Physical Testing Data

In order to evaluate the data obtained from each composite sample, the means and variances of the data sets were analyzed for statistical significance. Also, an expression for the determination of sample size was modified to yield a measurement of the probable error of the mean of the test results.

Comparison of the Means

In order to determine if there was a significant difference in the means of the two composite samples, the "Student's - t" test was applied to the data.

The following formulas were employed to compare the means of the samples (35):

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sigma \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}}$$

$$\sigma = \sqrt{\frac{N_1 S_1^2 + N_2 S_2^2}{N_1 + N_2 - 2}}$$

$$\gamma = N_1 + N_2 - 2$$

where

$\bar{X}_1$, $\bar{X}_2$ = mean values of the respective samples,

N_1, N_2 = sizes of the respective samples,

S_1^2, S_2^2 = variances of the respective samples,

γ = degrees of freedom.

The calculated value of "t" was located in the "t" distribution table using γ degrees of freedom, and the degree of significance determined from the probability level.

Comparison of the Variances

In order to compare the variances of the two composite samples, the F test was utilized.

The following formula was employed to determine the significance of the difference in the variances obtained (36):

$$F = \frac{S_1^2}{S_2^2}$$

where

F = F ratio,

S_1^2 = larger variance,

S_2^2 = smaller variance.

The calculated value of the F ratio was located in the F distribution table using (N-1) degrees of freedom. Significance at 95 and 99 percent probability levels was determined.

Probable Error of the Means

The modified equation used was as follows (37):

$$E = \sqrt{\frac{t^2 \sigma^2}{n}}$$

where

E = probable error* of the mean of the test results expressed in the units of the property under test,

t = constant depending on the probability level,

σ = standard deviation of individual test results,

n = number of test specimens.

The value of t used corresponds to a 90 percent probability level. The values of σ were determined from tests on both unblended and blended samples for each of the physical properties investigated.

The probable error of the mean of the blended sample was compared to the probable error of the mean of the unblended sample by substitution back into the equation given above. The number of tests required on the unblended sample was determined in order to achieve the probable error of the blended sample mean.

Dyed Fiber Tracer Tests

In order to conduct the dyed fiber tracer studies, a portion of the raw cotton stock was dyed. Raw stock was used for this purpose due to the difficulty encountered with dyeing the stock in sliver form. No

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*Probable error is defined in this case as the maximum probable difference between the mean of the test results and the true mean of the sample lot.

physical tests were performed on the stock used for tracer studies.

A direct dye, Pontamine Diazo Blue NA,* was chosen because of its strong affinity for cellulosic fibers and ease of application (38). Before dyeing, 200 grams of raw stock were scoured in an open steam vat. Then the vat was drained and eight liters of water were added to the dye bath. The dyestuff was pasted in a solution of cold water and Igepon T,** an anionic wetting agent. Sufficient boiling water was added to the paste to bring the dye into solution. Before the dye solution was added, 15 grams of soda ash were added to the dye bath to insure softness of the water. Then the dye solution was poured through a strainer into the dye liquor. One hundred grams of sodium chloride were added to the dye liquor.

The raw stock was immersed in the bath at 40 to 50 degrees Centigrade and raised to the boil over a period of 30 to 40 minutes. Dyeing was continued for one hour at the boil. After dyeing was completed, the vat was drained and a weak solution (20 liters of softener per liter of water) of fabric softener was added to the cotton to prevent excessive matting. Then the vat was drained and the cotton allowed to dry.

In order to conduct the fiber tracer studies, the raw stock was separated by hand into relatively small tufts and hand-fed to the opening apparatus. Three methods of feeding were used. The first method entailed feeding the blue and white tufts in a side-by-side manner. The second method was to feed the blue and white tufts in alternating lengths.

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*Manufactured by E. I. du Pont de Nemours and Company, Inc.

**Manufactured by General Aniline and Film Corp.

The third method entailed feeding a sandwich sample into the blending system. Also, a randomly mixed sample was prepared on the Shirley analyzer for determination of the blending effectiveness which would be expected for a random sample. In the random sample, the blue and white portions of cotton occurred in various portions of the composite sample in relatively large tufts.

CHAPTER V

DISCUSSION OF RESULTS

Physical Test Results

Physical tests were performed on the cotton specimens before and after blending to aid in the determination of the effectiveness of the blending system. The equipment and procedures described in Chapters III and IV were utilized to measure the properties of the fiber bundle strength, fiber fineness and fiber length distribution.

Fiber Bundle Strength

Twenty-five test specimens were selected from each composite sample before and after blending in order to measure the tenacity of the respective samples. The Pressley fiber bundle strength tester was used for these measurements as described in Chapters III and IV. Complete test results for each composite sample are given in Tables 12 and 13 of the Appendix. A summary of these data appears in Table 3 and the mean values are plotted in Figure 15.

Table 3. Summary of the Mean Values, Standard Deviations, Variances, and Percent Coefficients of Variation for the Pressley Fiber Bundle Strength Test

Sample	Mean Value (Grams per Tex)	Standard Deviation (Grams per Tex)	Variance $(SD)^2$	Percent Coefficient of Variation
Before Blending	48.79	3.22	10.37	6.60
After Blending	50.57	1.12	1.25	2.21

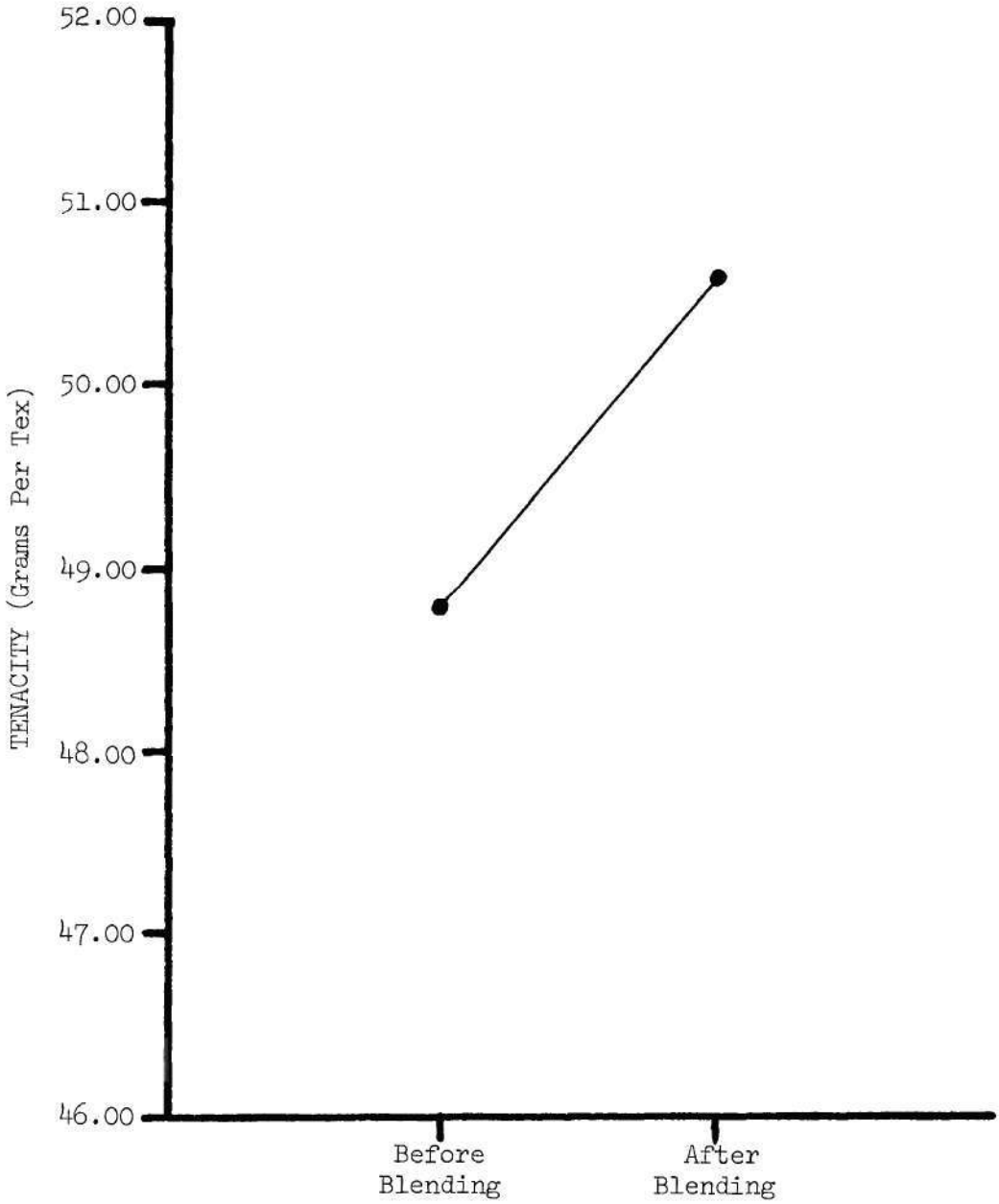


Figure 15. Mean Tenacities of Cotton Specimens Before and After Blending

As can be seen from the test results, the mean tenacity increased after blending. Application of the "Student's - t" test to the mean values indicated that the tenacity of the blended sample was significantly greater than the tenacity of the unblended sample. The standard deviation and percent coefficient of variation also showed a significant change after blending. The standard deviation decreased from 3.22 grams per tex for the unblended sample to 1.12 grams per tex for the blended sample. The percent coefficient of variation showed a corresponding decrease from 6.60 percent for the unblended sample to 2.21 percent for the blended sample. A decrease in the standard deviation and the percent coefficient of variation indicated that the dispersion of tenacity values about the mean was significantly less after blending.

The variance showed a decrease from 10.37 for the unblended sample to 1.25 for the blended sample. Application of the F test to these values showed that the decrease was significant.

The dispersion of the respective composite samples can be readily seen in the frequency distributions given in Figures 16 and 17. The significant decrease in dispersion in the blended sample indicated by the decrease in the standard deviation is quite obvious when the frequency distributions are compared.

Application of the probable error test described in Chapter IV indicated that the probable error of the mean tenacity of the blended sample was almost 300 percent less than that of the unblended sample. In order to achieve a precision this low for the unblended sample, 208 tests would be required for each composite unblended sample (as compared to 25 for the blended sample).

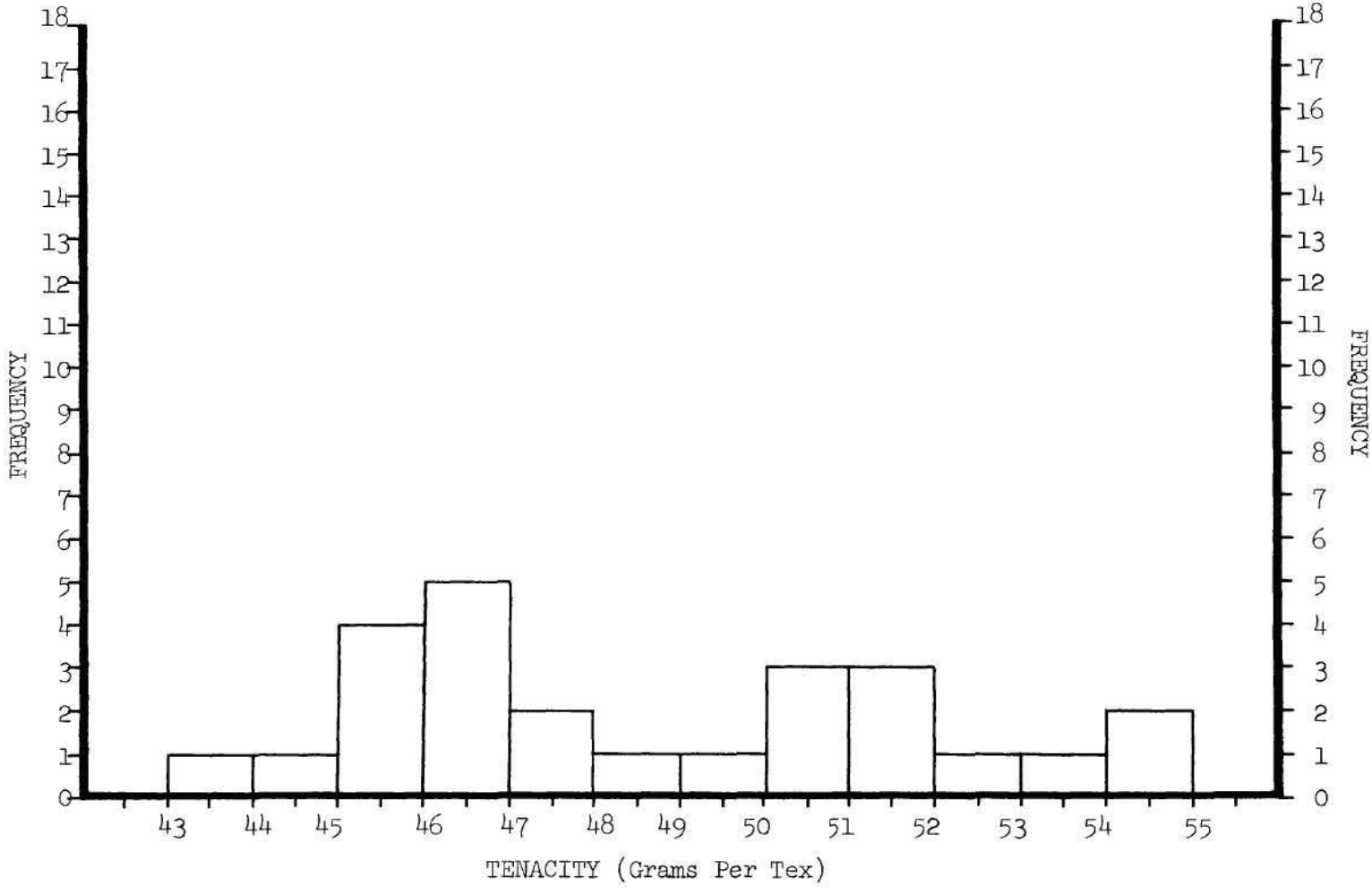


Figure 16. Frequency Distribution of Fiber Bundle Strength Measurements for Cotton Specimens Before Blending

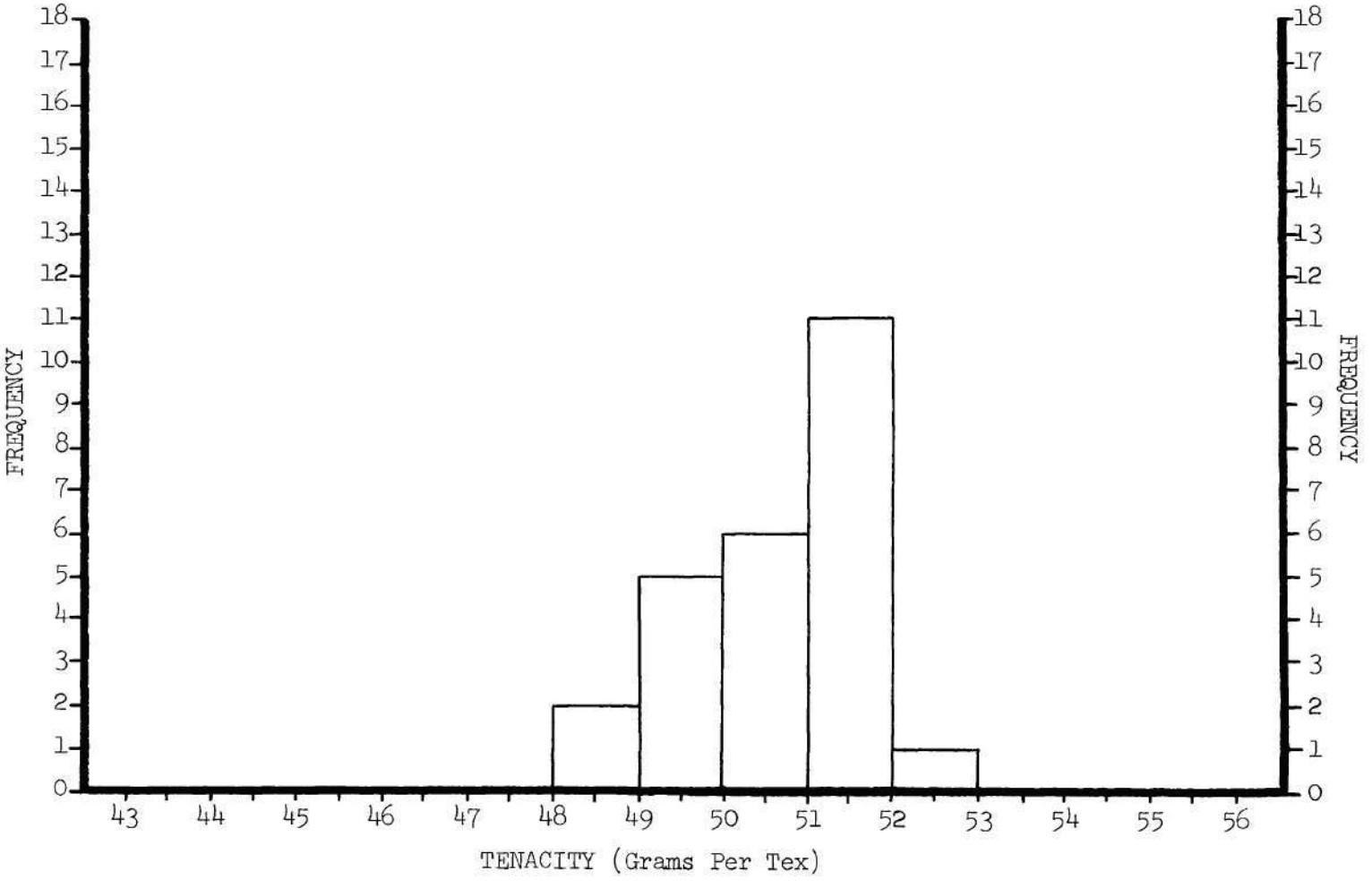


Figure 17. Frequency Distribution of Fiber Bundle Strength Measurements for Cotton Specimens After Blending

Careful consideration of the complete data for the fiber bundle strength tests indicated the desirability of blending cotton samples before testing. The uniformity of test results for the blended sample was obviously much greater than the uniformity of the test results for the unblended sample.

Fiber Fineness

Using the Fibronaire, as described in Chapters III and IV, fiber fineness measurements were performed for the cotton specimens selected before and after blending. A total of 50 specimens were tested, 25 from each composite sample. Results of the measurements are shown in Tables 14 and 15 of the Appendix. The results are summarized in Table 4 and the mean values are plotted in Figure 18.

Table 4. Summary of the Mean Values, Standard Deviations, Variances, and Percent Coefficients of Variation for the Fibronaire Fiber Fineness Test

Sample	Mean Value (Micrograms per Inch)	Standard Deviation (Micrograms per Inch)	Variance $(SD)^2$	Percent Coefficient of Variation
Before Blending	3.74	.11	.01	3.04
After Blending	3.75	.09	.01	2.49

As can be seen from the test results, no significant change in the fiber fineness was observed after blending. The "Student's - t" test verified that the slight change in the mean fineness was not significant. The standard deviation and percent coefficient of variation decreased slightly after blending.

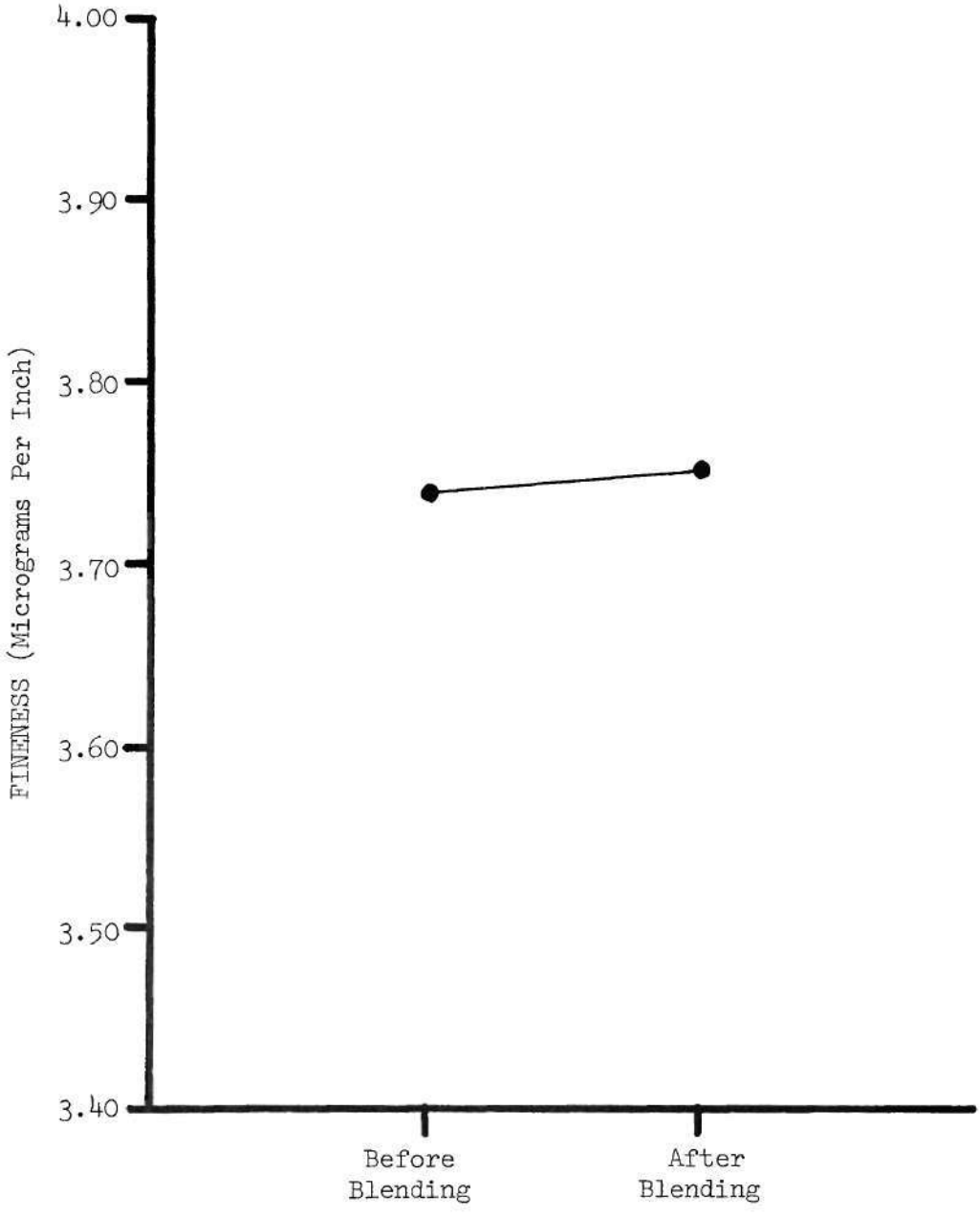


Figure 18. Mean Fineness of Cotton Specimens Before and After Blending

Utilizing the F test, it was determined that there was no significant change in the variance of the sample after blending.

Application of the probable error test showed that, for both the unblended sample and the blended sample, the probable error of the mean fineness was .03 microgram per inch for 25 tests. The equality of the probable error for both samples stemmed from the equality of the variances.

The results of the fiber fineness tests were largely inconclusive. Although the standard deviation and the percent coefficient of variation of the blended sample were slightly lower than those of the unblended sample, the decrease was deemed insufficient to allow conclusive deductions as to the effectiveness of the blending system.

Fiber Length Distribution

Using the Digital Fibrograph and Fibrosampler in the manner described in Chapter IV, fiber length distributions were obtained for the composite samples before and after blending. A total of 50 test specimens were selected, 25 from each composite sample. Complete test results for these measurements are given in Tables 16 through 19 of the Appendix. A summary of the data appears in Tables 5 through 7. The upper quartile length and mean length estimations were made by the use of a graphical solution developed by Louis and Fiori (39). The uniformity ratios were calculated in the manner described in Chapter IV. Average values of the mean length, upper quartile length, and uniformity ratio are plotted in Figures 19 through 21.

The average mean length increased slightly after blending, but application of the "Student's - t" test indicated that the increase was

Table 5. Summary of the Mean Values, Standard Deviations, Variances, and Percent Coefficients of Variation for the Digital Fibrograph Fiber Length Distribution Test

Sample	Average Mean Length (Inches)	Standard Deviation (Inches)	Variance $(SD)^2$	Percent Coefficient of Variation
Before Blending	1.118	.059	.003	5.258
After Blending	1.128	.059	.003	5.264

Table 6. Summary of the Mean Values, Standard Deviations, Variances, and Percent Coefficients of Variation for the Digital Fibrograph Fiber Length Distribution Test

Sample	Mean Upper Quartile Length (Inches)	Standard Deviation (Inches)	Variance $(SD)^2$	Percent Coefficient of Variation
Before Blending	1.334	.083	.007	6.192
After Blending	1.353	.135	.018	10.009

Table 7. Summary of the Mean Values, Standard Deviations, Variances, and Percent Coefficients of Variation for the Uniformity Ratios

Sample	Mean Uniformity Ratio	Standard Deviation	Variance $(SD)^2$	Percent Coefficient of Variation
Before Blending	46.6	3.8	14.4	8.112
After Blending	48.1	4.0	16.0	8.352

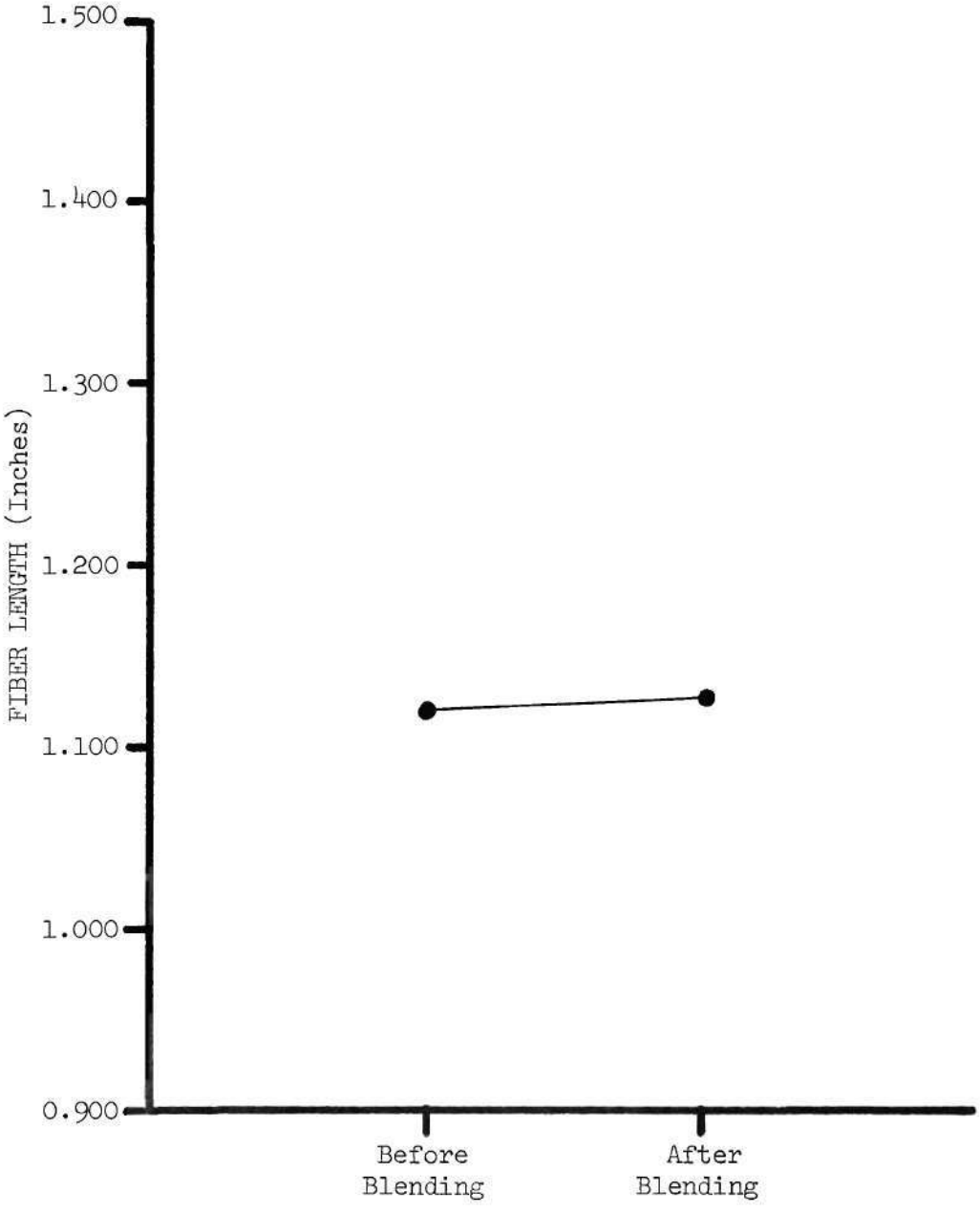


Figure 19. Average Mean Length Estimations for Cotton Specimens Before and After Blending

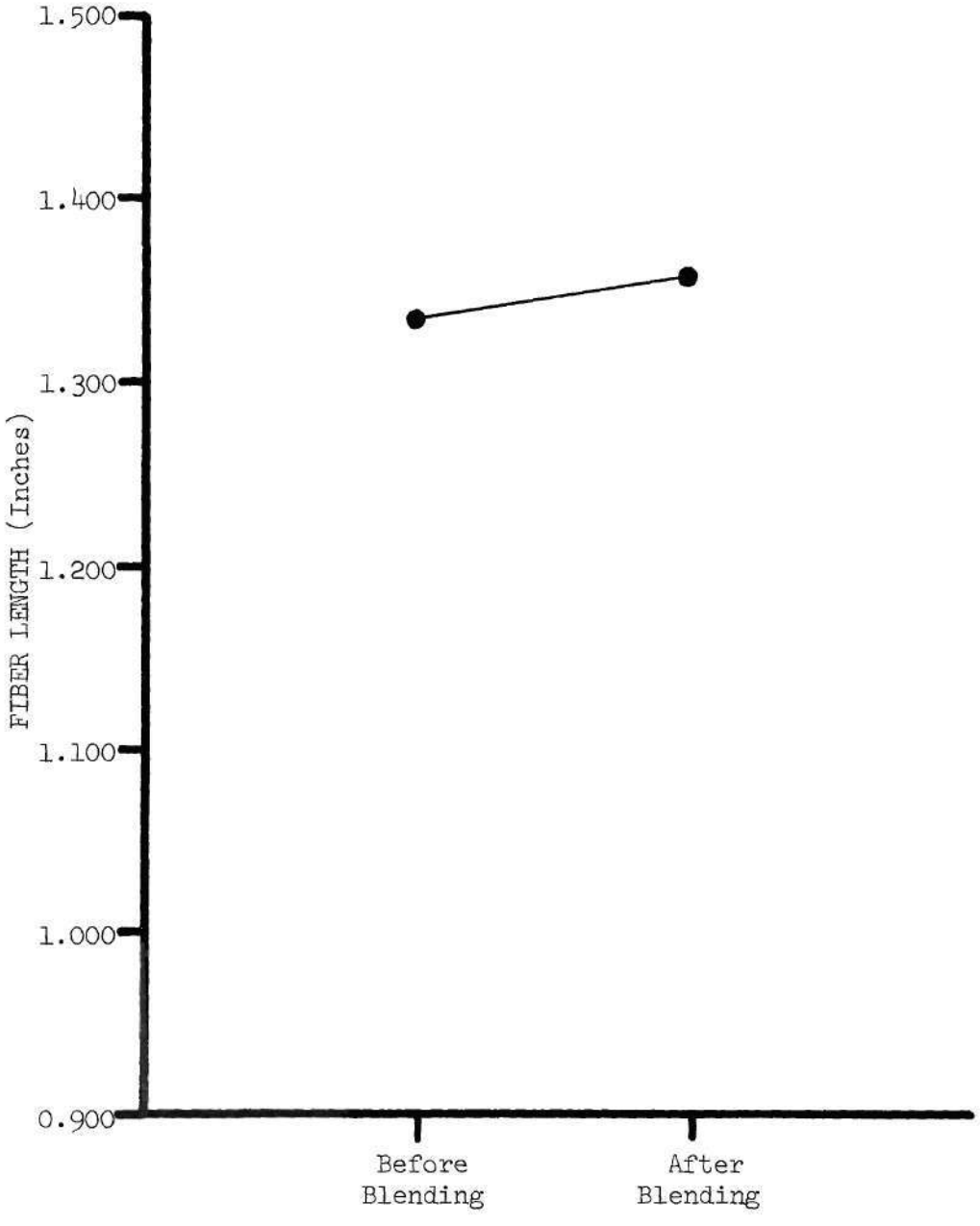


Figure 20. Mean Upper Quartile Length Estimations for Cotton Specimens Before and After Blending

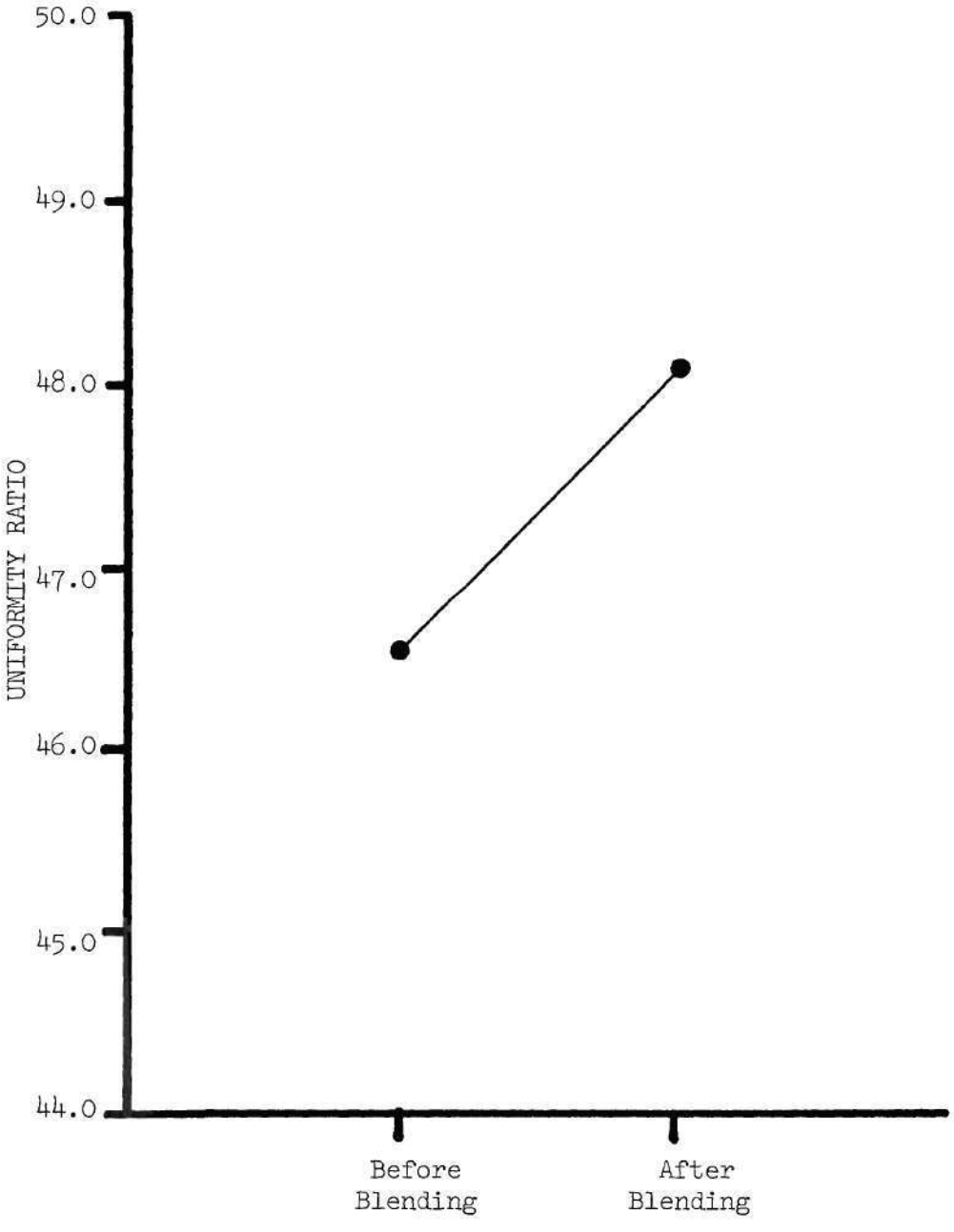


Figure 21. Mean Uniformity Ratios of Cotton Specimens Before and After Blending

not significant. The standard deviation showed no change and the percent coefficient of variation increased only a slight amount after blending.

Utilizing the F test for comparison of the variances, no difference in the variances of the two composite samples was observed.

Using the probable error test, the probable error of the mean length was calculated to be approximately 0.014 inch for both sample lots. The equality of the probable error was due to the equality of the variances.

The average upper quartile length also showed an increase after blending. Application of the "Student's - t" test indicated that this increase was not significant. The standard deviation and percent coefficient of variation also displayed an increase after blending. The increase appeared to be considerable when compared to such changes in other test results.

The F test revealed that the change in the variances was of questionable significance. The calculated F ratio of 2.57 fell outside the shaded region of the F distribution curve when the five percent point was considered, but fell inside the shaded region when the one percent point was considered. Thus the significance of the difference in the variances depended on which point was chosen. In this case, the five percent point was chosen and the difference in the variances was considered to be significant.

Application of the probable error test revealed that the probable error of the mean value of the blended sample was approximately 155 percent higher than that of the unblended sample. The larger probable error of the blended sample was attributed to its higher variance.

The uniformity ratios of the respective sample lots showed a slight increase after blending. This indicated that the ratio of short fibers to long fibers increased after blending. Application of the "Student's - t" test showed that this increase was insignificant. There was also an increase in the standard deviation and percent coefficient of variation for the blended sample. These increases were slight and were considered to be insufficient for conclusive deductions.

The F test indicated that there was no significant difference in the variances of the respective sample lots.

Using the probable error test, the probable error of the samples was shown to differ only slightly. The probable error of the mean uniformity ratio of the blended sample was slightly greater than that of the unblended sample, but the difference was not considered to be significant.

The data obtained from the fiber length distribution measurements offered no conclusive results as to the effectiveness of the blending system. In most of the data, it appeared that the non-uniformity of the sample was increased by blending, but this was hardly basis for any rigid conclusions.

Discussion of Physical Test Results

Generally speaking, the physical test results failed to give conclusive evidence of the blending effectiveness of the system under investigation. While the fiber bundle strength data indicated that blended samples gave a more accurate value for the entire bale sample, the other test results failed to substantiate this conclusion. It must be noted that there were two possible sources for error in the test results.

In using the draw frame as a feed device, the sample opening desired was not attained. At best, the draw frame was capable of opening only small tufts of the sample. Almost no individual fiber separation was attained, and in many cases the tufts which were fed into the system were much too large for optimum blending (Figures 33 through 35 of the Appendix).

The other possible source of error lies in the lack of operator technique during the determination of the properties of fiber fineness and fiber length distribution. However, the fiber bundle strength measurements were performed by experienced and highly capable technicians. Operator bias could have had little effect on the bundle strength determinations since the measurements were performed by personnel with no prior knowledge of the purpose of the investigation. Also, the sample specimens were coded so that the type of sample being tested was not known to the technicians.

The shortcomings of this particular phase of the investigation were anticipated before the study was conducted. However, due to the lack of a suitable feed device, the draw frame was one of the few alternatives which proved to materialize. The lack of opening was the primary reason the draw frame was not chosen for the dyed fiber tracer studies. It is believed that, if the opening performance of the draw frame had been as effective as the performance of the specially constructed opener described in Chapter III, the physical test results would have been more conclusive.

As for the lack of operator technique on the part of the author in the determination of fiber fineness and fiber length distribution,

this was only a possible source of error. Modification of the testing procedure was the primary reason for eliminating the alternative choice of having these tests performed by experienced personnel. Both the operation and procedure for determining fiber fineness and fiber length distributions are well defined and relatively simple so operator technique should not have had any extreme influence on the test results.

Dyed Fiber Tracer Studies

As mentioned in Chapters III and IV, the use of dyed fiber tracers was employed to determine the blending effectiveness of the system. The methods utilized provided an excellent evaluation of the blending achieved in several dimensions of the sample. The results and discussion of these methods are given in the following sections.

Blending Across the Width of the Sample

In order to evaluate the blending achieved across the width of the samples, equal weights of dyed and undyed cotton samples were fed into the blending system in a side-by-side manner, Figure 22. The dyed portion of the sample was placed adjacent to the inner wall of the blending duct. The undyed portion of the sample was placed adjacent to the outer wall of the duct. In this way, it was possible to observe the relatively small dyed tufts of cotton as they traveled through the system and permeated through the group of undyed cotton tufts. For final evaluation of the system in its entirety, the samples were collected from the rotating screen, inspected and photographed.

Excellent blending was achieved across the width of the samples. The blended sample shown in Figure 23 was representative of the samples blended by the side-by-side feeding method. Color distribution was

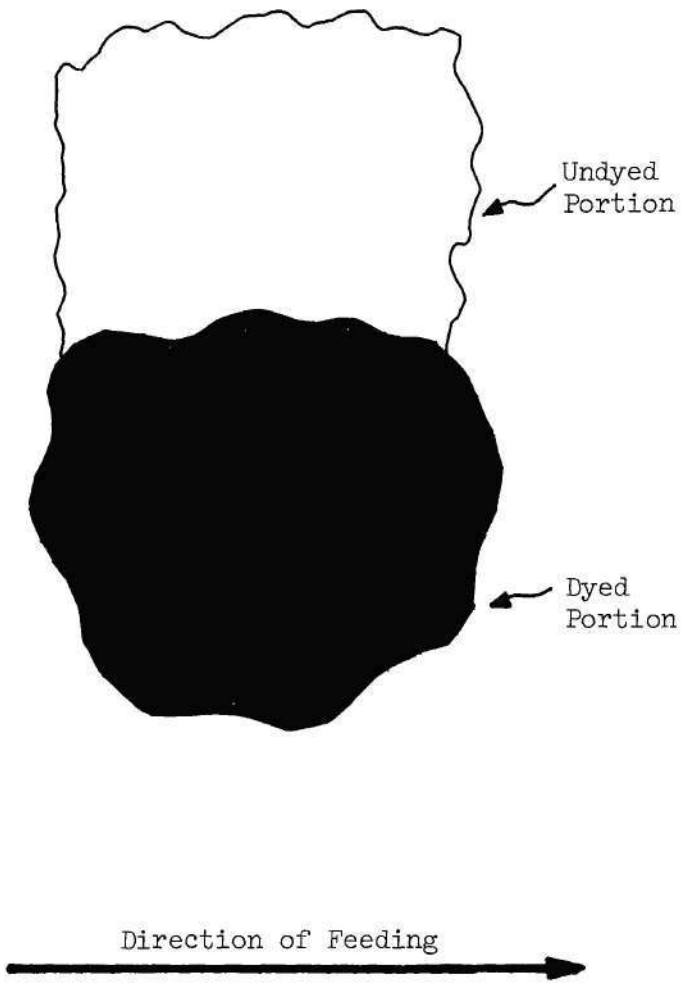


Figure 22. Side-By-Side Method of Sample Feeding

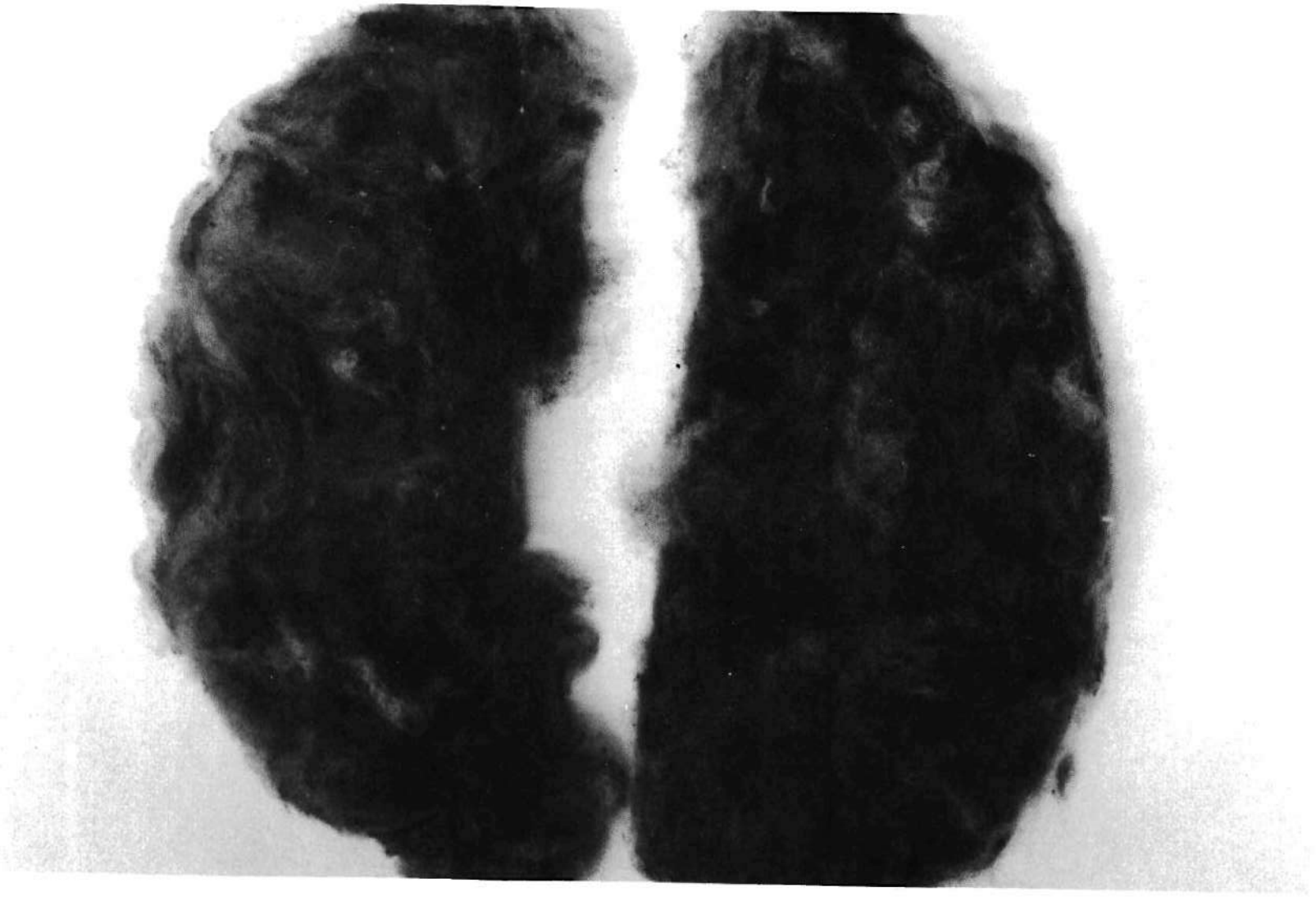


Figure 23. Blended Sample Obtained by the Side-By-Side Method of Feeding

uniform throughout the sample. Distinct tufts of dyed or undyed fibers were almost non-existent. The isolated occurrences of such tufts were attributed to improper opening of the samples.

As can be seen from the control samples of dyed and undyed cotton (Figure 24), the overall shade of the blended sample fell between the dark shade of the dyed cotton and the light shade of the undyed cotton.

Blending effectiveness of the system in this case was attributed to the effect of the corner flow on the tufts and the distribution caused by the rotating collection screen.

Blending Along the Length of the Sample

In order to evaluate the blending achieved along the length of the samples, equal weights of dyed and undyed cotton were fed into the blending system in a tandem arrangement, Figure 25. The dyed portion was placed across the width of the feed device and the undyed portion of the sample was placed directly behind the dyed portion. The samples were collected from the screen, inspected and photographed.

Poor blending was achieved along the length of the samples. The blended sample shown in Figure 26 was representative of the samples blended by the tandem feeding method. All samples obtained with this method of feeding displayed stratification into two layers. Figure 26 shows the top and bottom layers of a single sample. Due to the physical nature of cotton, the boundary region of the samples was not distinct, but it was evident that long-range blending throughout the length of the samples was not achieved.

The failure to obtain satisfactory blending along the length of the samples was attributed to the fact that the time delay within the

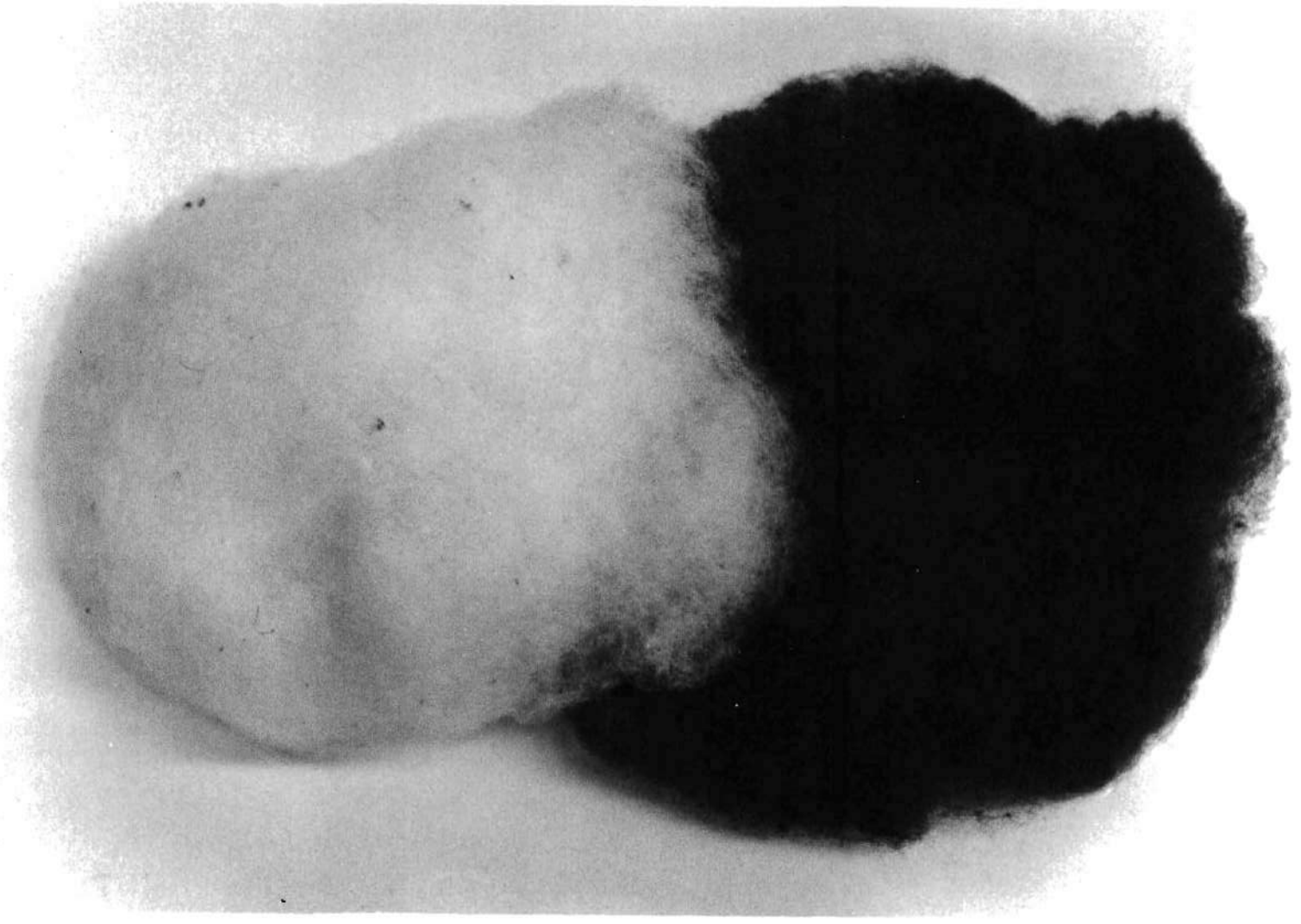


Figure 24. Control Samples of Dyed and Undyed Cotton

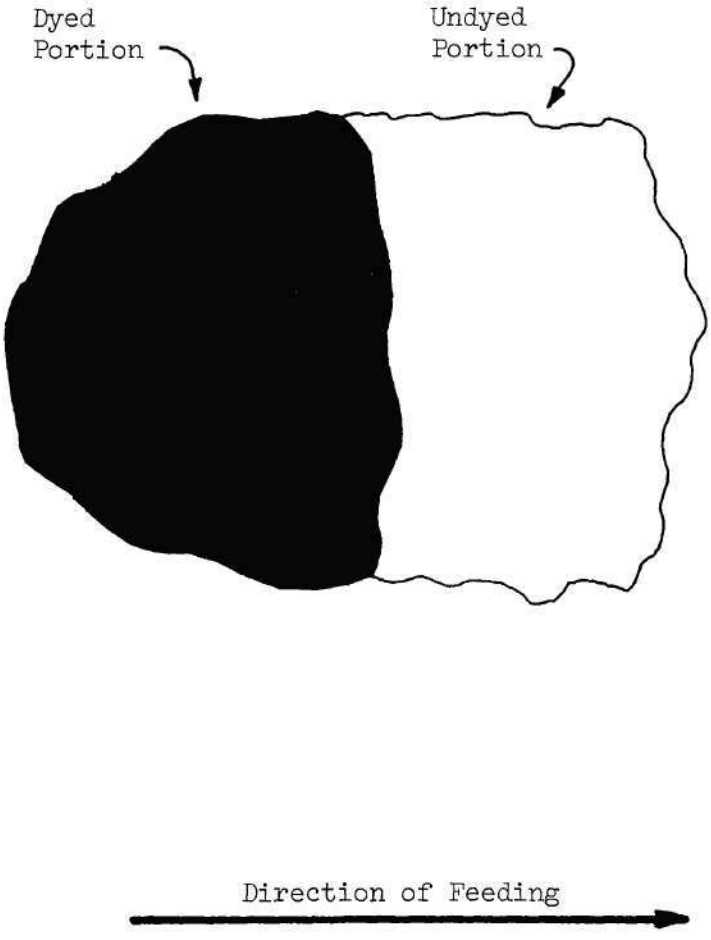


Figure 25. Tandem Method of Sample Feeding

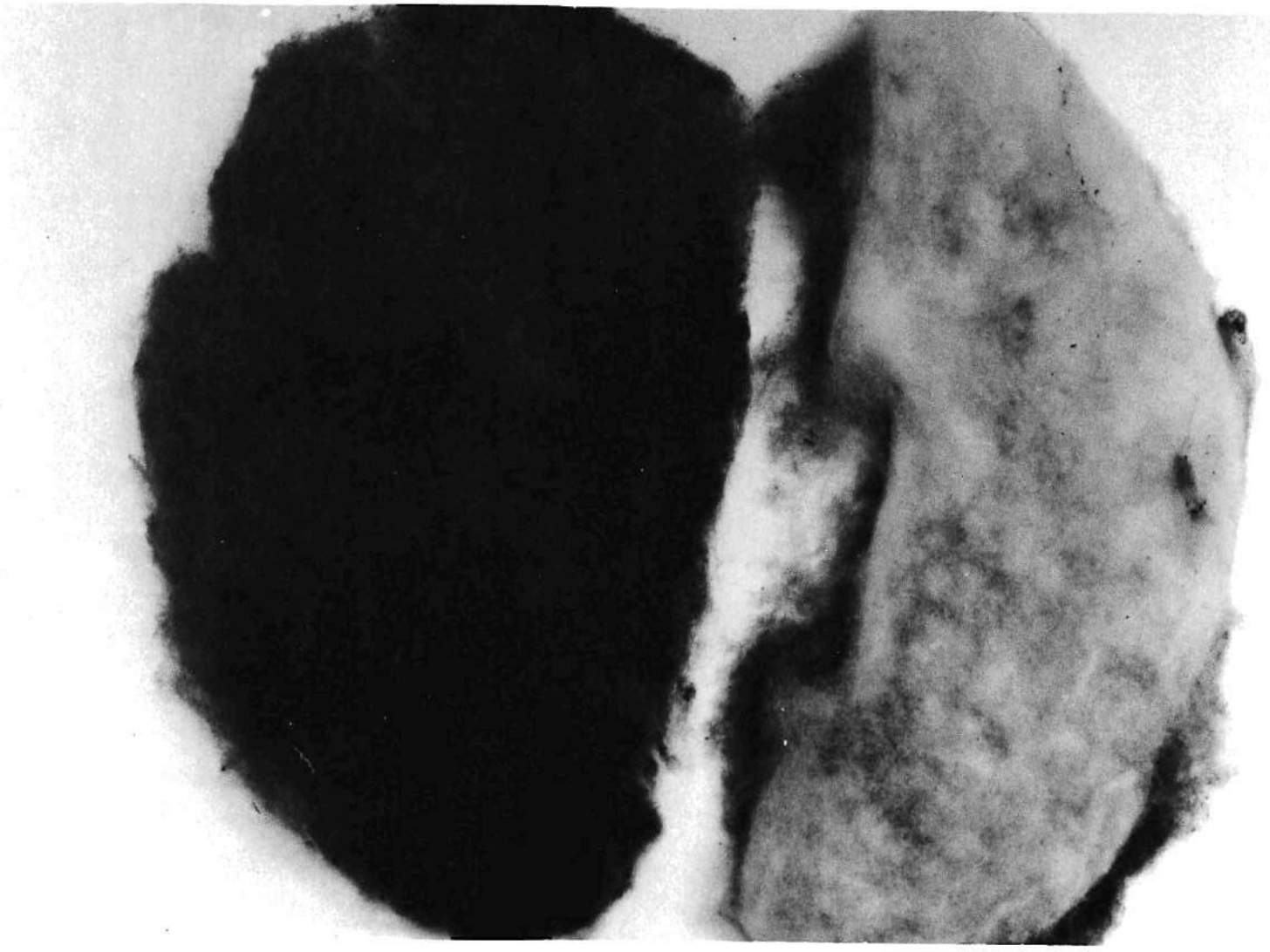


Figure 26. Blended Sample Obtained by the Tandem Method of Feeding

system was extremely small. The cotton particles were traveling at a relatively high speed and the difference in particle speeds and lengths of travel was not great enough to allow a significant time difference in their respective arrivals at the collection screen.

The tandem feeding method was modified slightly to enable further evaluation. Several alternating portions of dyed and undyed cotton were fed into the system, as shown in Figure 27. The stratified sample shown in Figure 28 was representative of the blended samples obtained. The stratified layers of dyed and undyed cotton were still clearly present in the blended samples.

Blending Through the Depth of the Sample

In order to evaluate the blending effectiveness achieved through the depth of the samples, a sandwich layer sample was prepared by the tandem method of feeding. The blended samples were obtained by feeding this sandwich layer sample into the blending system. The samples were then collected on the rotating screen, inspected and photographed.

Excellent blending was achieved through the depth of the samples. As can be seen in Figure 29, color distribution of the dyed fiber tracers was uniform throughout the sample. Blending effectiveness of this method of feeding was attributed to the effect of the corner flow on the particles and the distribution caused by the rotating collection screen.

The sample obtained by this method can also be thought of in another way. Since the sandwich layer sample was obtained by tandem feeding initially, this sample may be thought of as a blended sample which has been blended in all three dimensions (width, length and depth) by a two process operation. On the first pass through the system, the

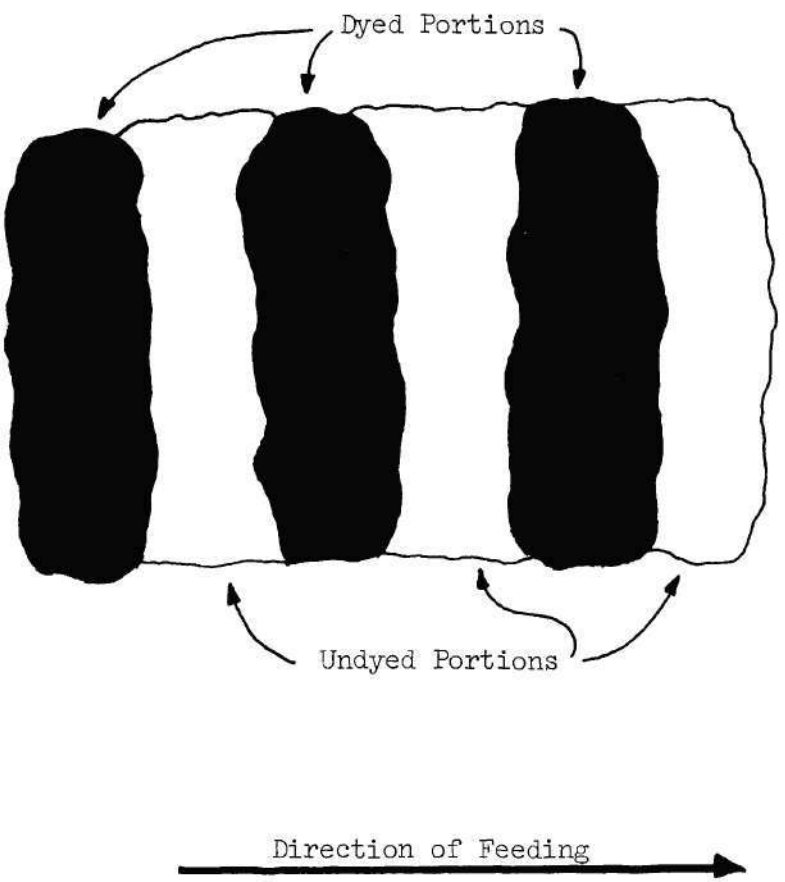


Figure 27. Modified Tandem Method of Sample Feeding

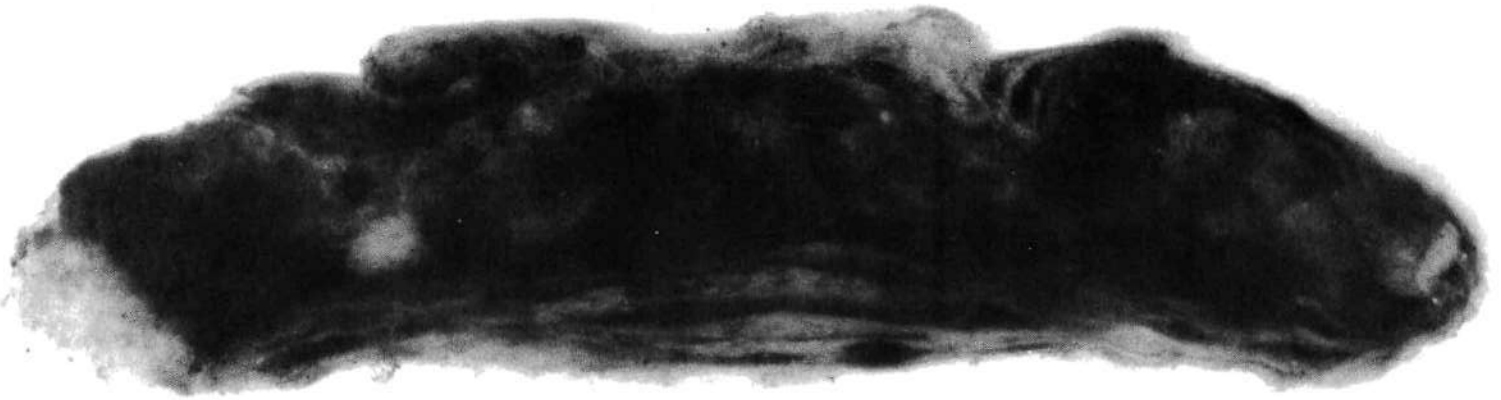


Figure 28. Blended Sample Obtained by the Modified Tandem Method of Feeding

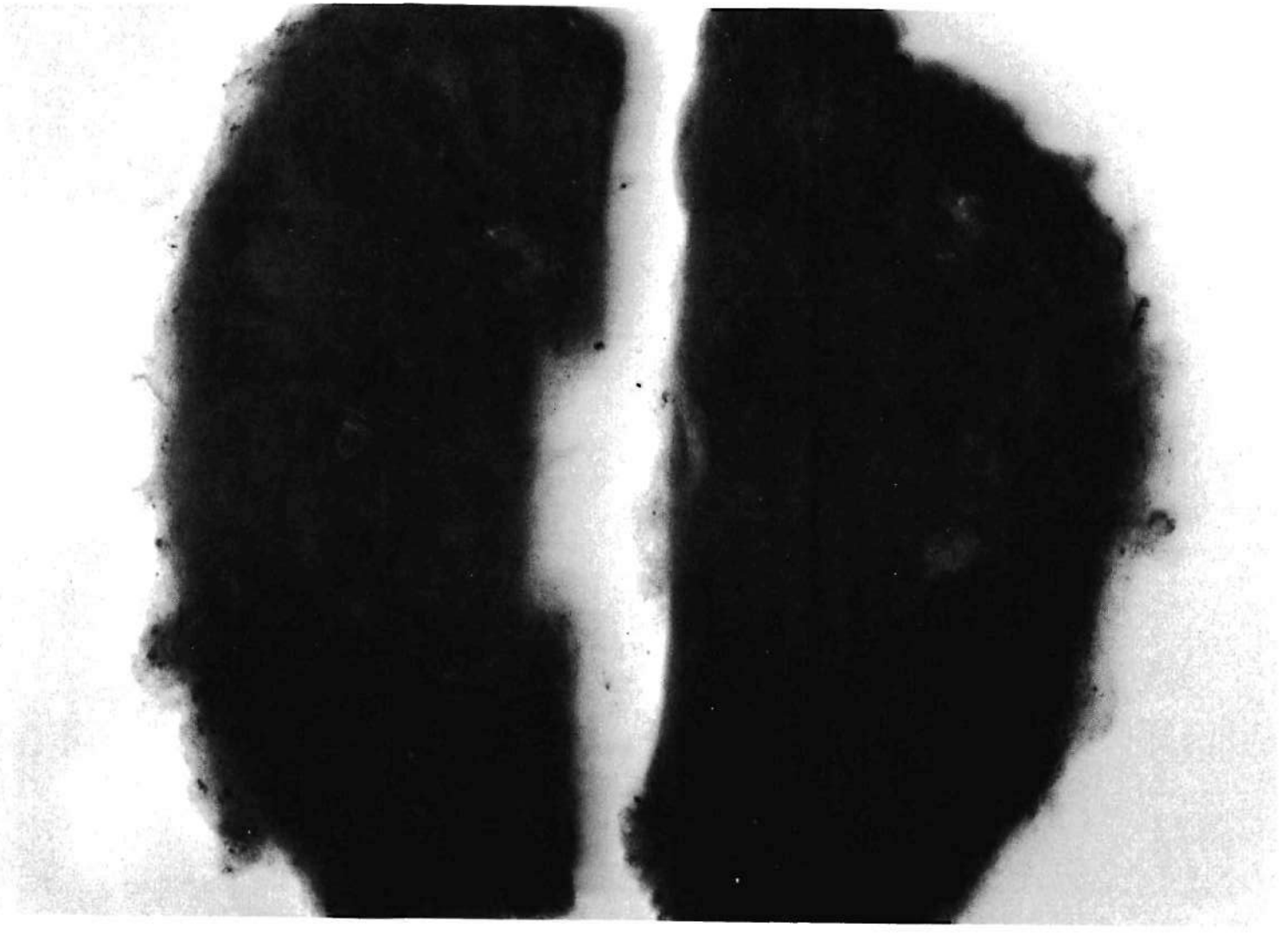


Figure 29. Blended Sample Obtained by the Sandwich Layer Method of Feeding

original sample was blended across the width and through the depth of the sample. On the second pass through the system, the primary blended sample was again blended across its width and through its depth. But a change in the original dimensions has occurred. The original length dimension becomes a depth dimension when collected on the screen. Subsequent feeding of this primary blended sample through the system results in the random distribution in all three dimensions. There is a complex interaction attributable to the method of feeding, method of collection, and the effects of the corner flow and rotating collection screen. A simple illustration of this change in dimensions principle is given in Figure 30.

Random Blending of the Sample

A random sample consisting of portions of dyed and undyed cotton was prepared on the Shirley analyzer. This random sample is shown in Figure 31 along with the blended sample obtained.

Excellent blending was achieved for the random sample. This sample could very easily be the most representative sample prepared. It cannot necessarily be assumed that the rigid conditions of the samples prepared for evaluation of width, length and depth blending effectiveness will occur in an average composite bale sample. If the assumption of random distribution of the subsamples throughout the composite bale sample is feasible, poor blending along the length of the sample would be of minor significance.

It should be noted that, when random distribution throughout the bale sample occurs, this does not necessarily eliminate the desirability of preblending bale samples before testing. Even in a random distribution,

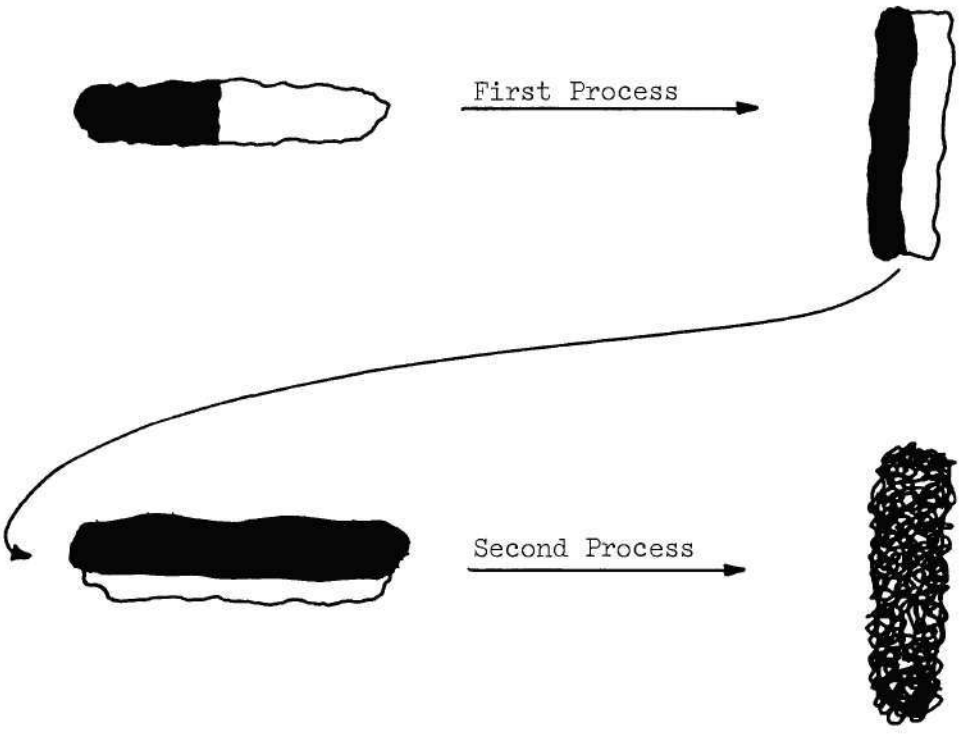


Figure 30. Schematic Diagram Showing Principle of Change in Dimensions in Two Process Blending Operation

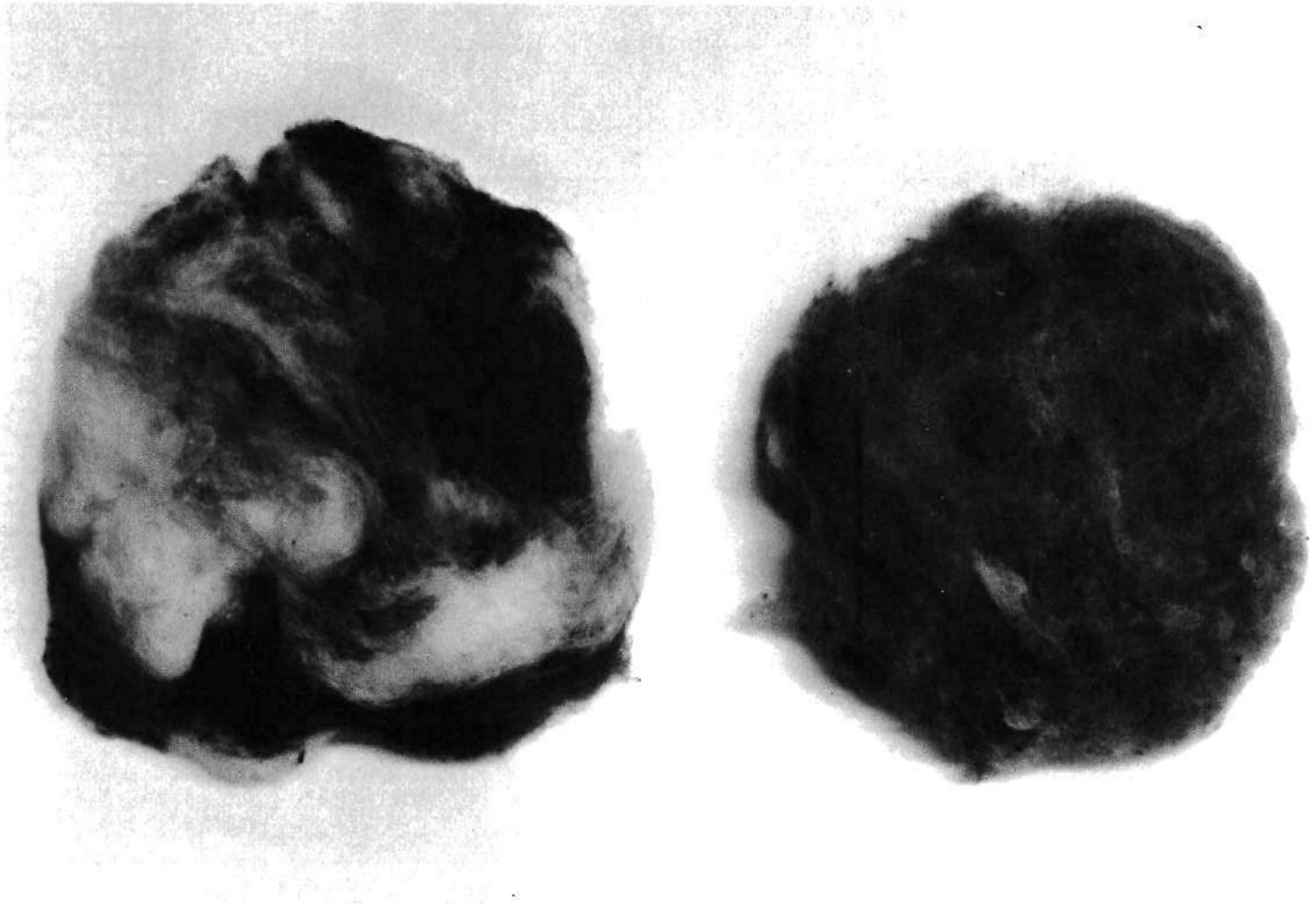


Figure 31. Random Coloration Mixture Before (Left) and After (Right) Blending

specimens selected from different areas of a bale sample would yield different physical test results. Obviously the uniformity of such test results would be a function of the uniformity of the bale sample. Indeed, this was shown by the physical tests performed on the unblended samples in this investigation. The sole purpose of this preblending is to minimize the non-uniformity of the bale sample and obtain an average which will relate the physical properties of the entire bale.

General Behavior of the Cotton Particles Within the Blending System

A general qualitative discussion of the behavior of the cotton particles within the blending system can be offered to explain the apparent effectiveness of blending which was achieved. Due to the complex nature of the flow within the system, a quantitative analysis would be extremely difficult and was not feasible.

The particles enter the system at the entrance to the duct. This input position is a function of the position of the particle within the original sample. As the particles travel along the initial straight portion of the duct, they generally follow paths which approximate the streamlines of the flow.

As the particles begin to feel the influence of the corner flow, they will not respond to the change in direction of the flow as rapidly as the streamlines. The particles will drift away from the streamlines and assume paths of increasing radius. The deviation from the streamline will be a function of the weight of the particle and the cross-sectional area of the particle presented to the flow. Generally, in a

particle-accelerated-by-flow situation such as this, particles with relatively larger cross-sectional areas (and, hence, higher drag forces) will tend to follow the streamlines more closely. Also, particles which have higher weights (and, thus, have more inertia) will tend to deviate from the streamlines to a greater extent. Thus, particles which have higher weight-to-cross-sectional area ratios will deviate from the streamlines more and swing to paths of larger radii. Similarly, particles which have relatively low weight-to-cross-sectional area ratios will follow the streamlines more closely and assume paths of relatively smaller radii.

When the particles reach the entrance to the delay system, they will have assumed distinct paths of travel. The particles will be isolated to a given extent in these paths by the vertical struts of the delay system. Thus, the particles will have reached their respective output positions when they enter the delay system. The output position for each particle will be a function of its initial input position and its sectional density.

As the particles reach the rotating collection screen, they are redistributed according to their time of arrival and their position across the width of the duct. Particles which have low weight-to-cross-sectional area ratios will travel at faster speeds and will travel in shorter paths. Therefore, these particles will reach the collection screen before particles which have higher sectional densities. In the short time period between the arrival of these particles, the rotating collection screen will revolve a slight amount. Thus, the rotation of the screen will further place the particles out of position with respect

to each other. Obviously, particles which travel nearer the inner wall or outer wall of the duct will be displaced to a greater extent than those which travel near the center of the duct due to the difference in the peripheral velocity of the screen.

Other Observations

The blended samples displayed no obvious detrimental effects induced by the blending system when compared to the unblended samples. There was no apparent increase in the nep content of samples after blending (Figure 32).

The concentration of cotton in the blending system was sufficiently low to allow relatively independent particle action. In the dyed fiber tracer tests, the dyed particles were observed to permeate through the undyed particles until their respective paths were established. An insignificant amount of particle aggregation was observed. This particle aggregation was considered undesirable since it would, in effect, offset the opening of the cotton sample and result in poor blending.

It was observed that the rough edges on the Plexiglas and electrostatic buildup caused a significant amount of cotton tufts and fibers to hang at the entrance of the delay system. Due to the relatively high fiber-to-fiber friction associated with cotton, a larger buildup of cotton was observed when larger sample sizes were blended. Also, the buildup was observed to be proportional to the particle size passing through the system. Smaller particles produced by the special opener suffered less buildup than the relatively larger particles introduced to the system by the draw frame.

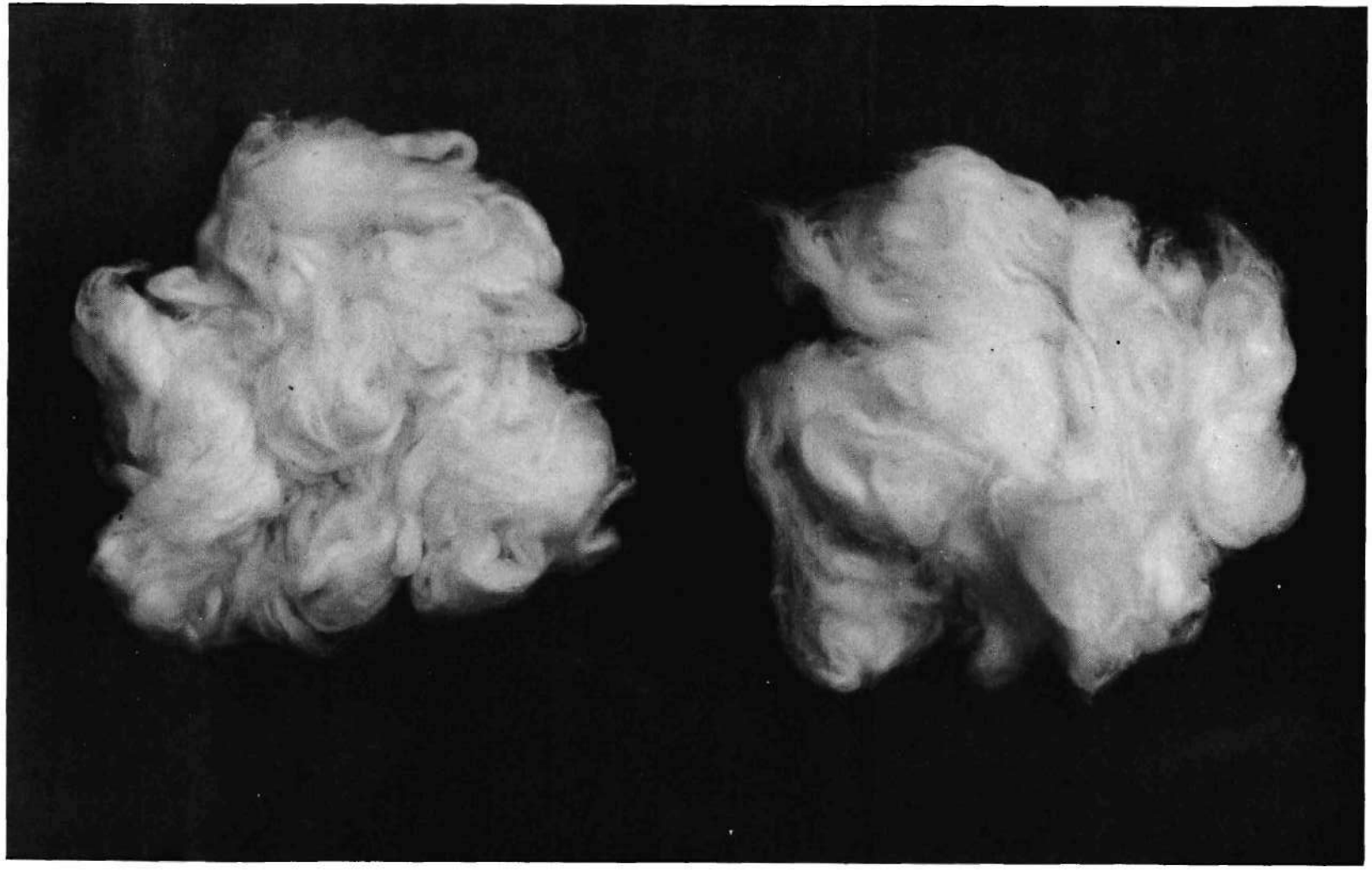


Figure 32. Samples of Unblended (Left) and Blended (Right) Cotton

Less than one percent loss of cotton fibers was observed when a 50 gram sample was blended. All of the loss was attributed to the poor vacuum seal between the rotating collection screen and its static frame.

As the sample tufts and fibers collected on the rotating screen, the peripheral velocity of the screen gradually decreased. This was not unusual since the buildup of cotton caused the vacuum seal to become more effective and more frictional resistance occurred between the rotating screen and its static frame.

CHAPTER VI

CONCLUSIONS

The following conclusions are based on physical test data obtained from this investigation, examination of the dyed fiber tracer samples, and processing observations.

The physical test results obtained from fiber fineness measurements and fiber length distribution measurements failed to offer any conclusive indication of the blending effectiveness of the system. The properties of fineness and length were not altered by the blending system.

The tenacity measurements obtained from the fiber bundle strength tests indicated that the uniformity of the blended sample was considerably higher than that of the unblended sample. This increase in uniformity was considered to indicate that the blending system performed satisfactorily and that any single tenacity value chosen from the 25 values would closely approximate the mean value of the entire blended sample.

The dyed fiber tracer portion of the investigation indicated that excellent blending effectiveness was achieved across the width of the sample and through the depth of the sample. This blending effectiveness was attributed to the right angle portion of the system and the rotating collection screen.

Blending along the length of the sample was observed to be almost

non-existent. Failure to obtain any long-range longitudinal blending was attributed to the relatively high velocity of the particles which held the time delay within the system at a very low value.

There were no detrimental effects, such as nep formation, induced by the blending system.

Cotton concentration within the system was sufficiently low to allow relatively independent particle behavior and to prohibit particle aggregation within the system prior to collection on the rotating screen.

Considerable buildup of cotton tufts and fibers was observed at the entrance to the delay portion of the system. This was attributed to the presence of rough edges on that portion of the apparatus and the buildup of static electricity on the Plexiglas. The amount of buildup of the cotton particles was observed to be proportional to the particle size.

CHAPTER VII

RECOMMENDATIONS

During this investigation, several related areas of interest were discovered which deserve extensive research. It is suggested that further studies be conducted in these areas in order to successfully solve the problem of preparing cotton specimens for physical testing.

Research in the area of pneumatic delay systems applicable to this blending system should be conducted. The theory of inducing a time delay within the system in order to achieve longitudinal blending has significant merit. Successful design and application of a delay system to this blending system would allow blending in three dimensions.

The complex fluid behavior associated with this type of system deserves extensive study. It is suggested that the parameters of the fluid flow and the dynamics of particle behavior in such a system be subjected to an engineering analysis.

It is also recommended that a more efficient opening device which inflicts minimal fiber damage to the samples be utilized in the physical testing portion of this investigation. It was pointed out that the failure of the draw frame to open sufficiently small tufts of cotton was a possible source of error in the inconclusive test results obtained for fiber fineness and fiber length distribution. It is possible that use of a more efficient opener would change the apparently insignificant data considerably. Using such an opener would also allow the use of raw cotton

stock taken from the bale instead of card sliver in the physical testing portion of the investigation. This could possibly afford a more realistic study in the preparation of bale samples for physical testing purposes.

The study of composite sample variation compared to the variation within each subsample should be conducted. Such a study would offer information which could dictate the significance of long-range longitudinal blending effectiveness. It is recommended that sample lots of both uniform and non-uniform physical properties be studied and the variation significance compared.

APPENDIX

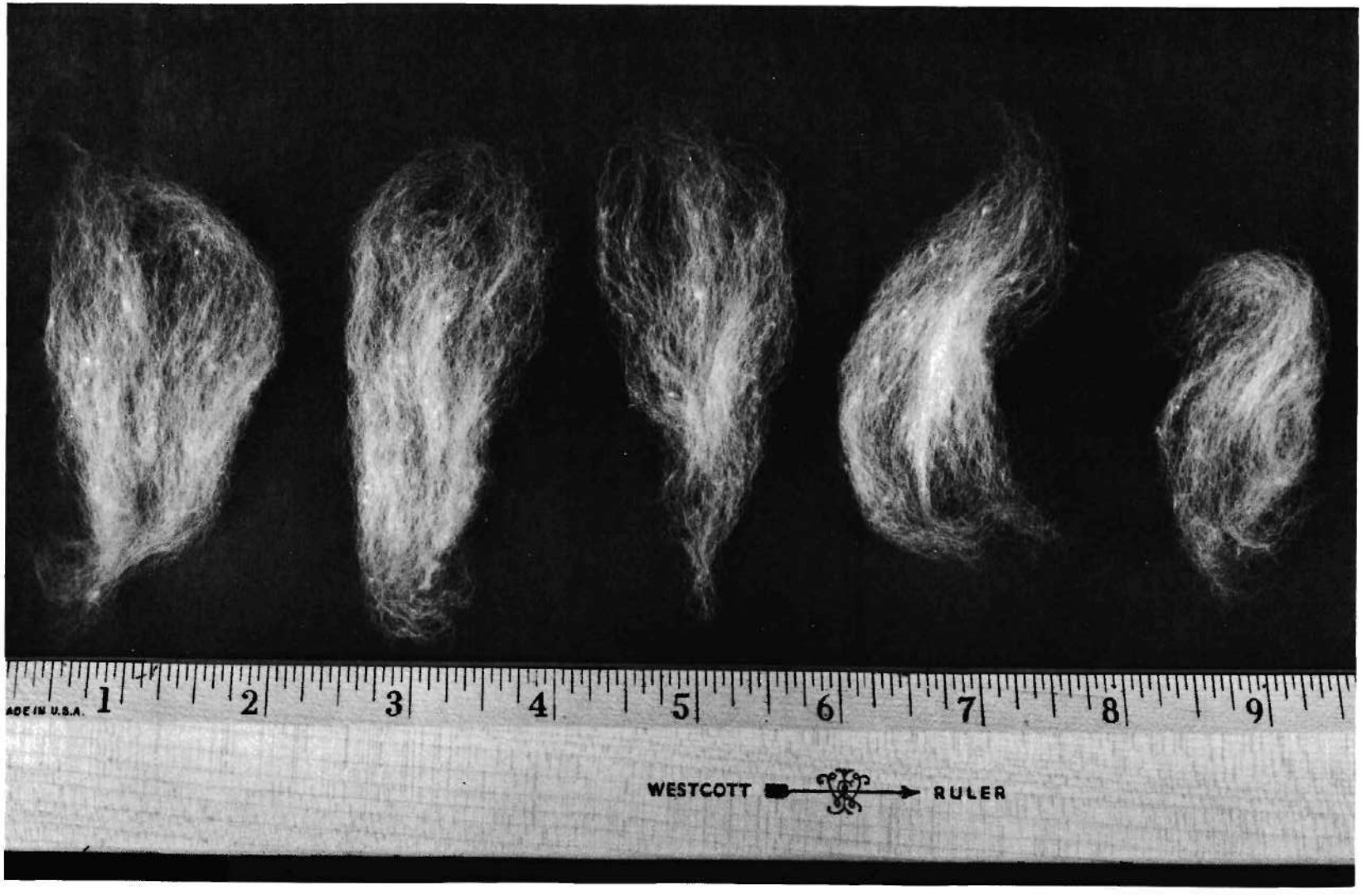


Figure 33. Average Tuft Sizes of Cotton Produced by Shirley Miniature Draw Frame

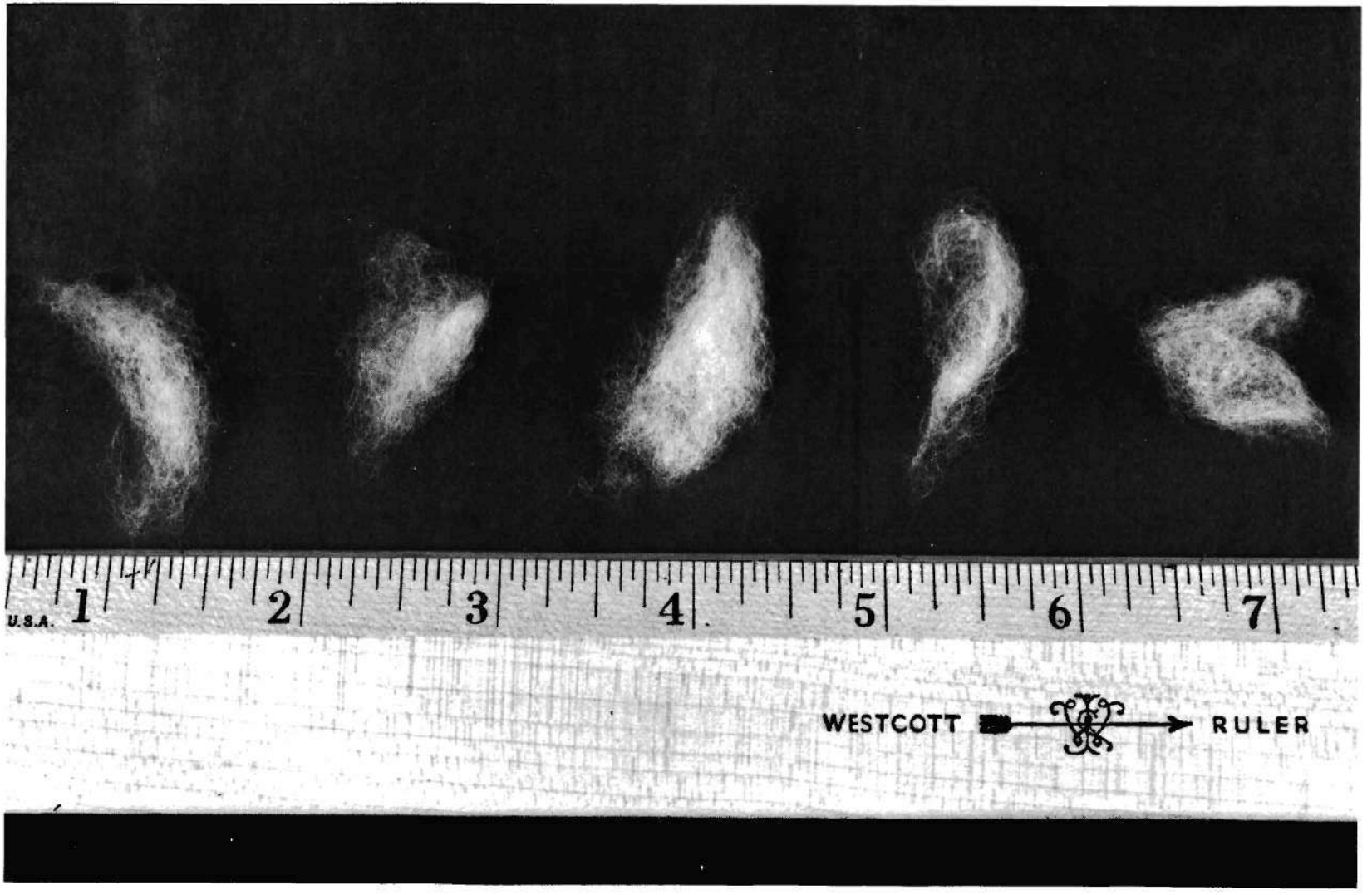
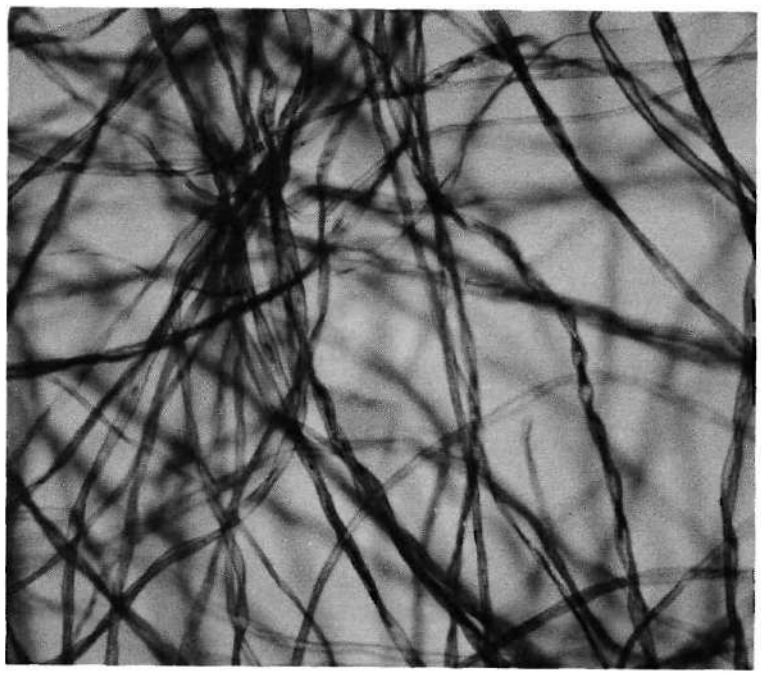
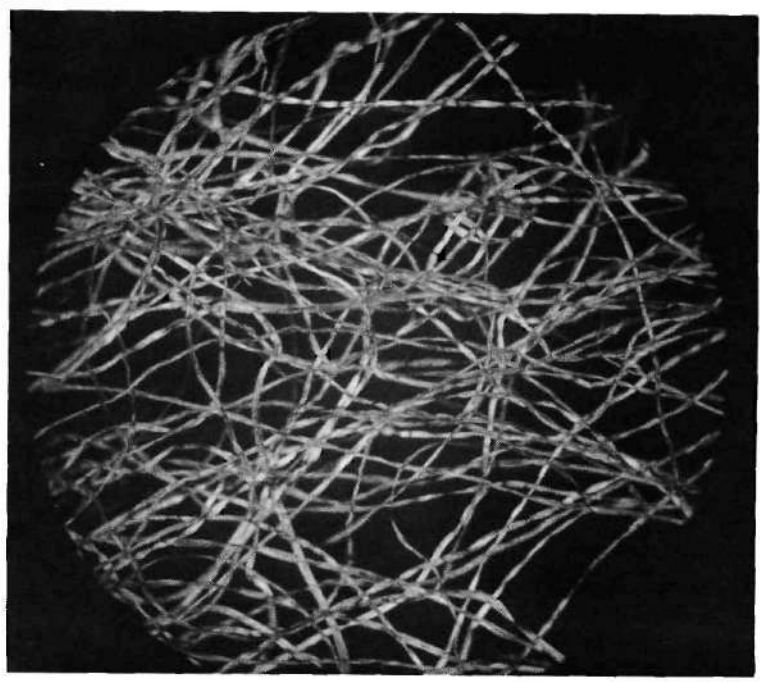


Figure 34. Average Tuft Sizes of Cotton Produced by the Special Opener



(a)



(b)

Figure 35. Photomicrographs of Cotton Fibers (a) 100X, (b) 35X

Table 8. Operating Speeds and Dimensions of the Principal Parts of the Stanford Research Institute Cotton Sample Blender

FEED ROLLS	One Inch Diameter
	Seven Revolutions Per Minute
	Smooth Top Roll
	Fluted Bottom Roll
LICKER-IN	2.875 Inches Diameter
	6000 Revolutions Per Minute
	Nylon Brush
CONDENSER	2.5 Inches Diameter
	13 Revolutions Per Minute
	Perforated Stainless Steel
DOFFER ROLLS	One Inch Diameter
	17 Revolutions Per Minute
	Both Rolls Fluted

Table 9. Operating Data for the Shirley Miniature Draw Frame

ROLL DIAMETERS	
All Top Rolls (Cushioned)	1.438 Inches
Bottom Rolls (Fluted)	
Front Roll	1.500 Inches
Second Roll	1.250 Inches
Third Roll	1.500 Inches
Back Roll	1.500 Inches
DRAFT	
Back Roll to Third Roll	2.00
Third Roll to Second Roll	1.03
Second Roll to Front Roll	5.25
Total Draft	10.50
RATCH	
Front Roll to Second Roll	1.500 Inches
Second Roll to Third Roll	1.375 Inches
Third Roll to Back Roll	1.875 Inches

Note: All rolls are nine inches wide.

Top rolls have 40 pounds weighting.

Table 10. Operating Data for the Specially Constructed Opener Used in the Dyed Fiber Tracer Studies

FEED ROLLS	DIAMETER	SPEED
Top Roll (Smooth)	1.000 Inch	7 RPM
Bottom Roll (Fluted)	1.000 Inch	7 RPM
LICKER-IN	**DIAMETER**	**SPEED**
Nylon Brush	2.875 Inches	6000 RPM

Note: Feed rolls and Licker-in are 11 inches wide.

Effective width of Licker-in is approximately 10 inches.

Table 11. Specifications for the Fiber Tracer Dye Bath

DYE	Direct Blue 126
	Pontamine Diazo Blue NA*
	Concentrated (200 Percent)
	12 Grams
STOCK	Raw Cotton Stock
	200 Grams (Dry Weight)
LIQUOR RATIO	40:1
WETTING AGENT	Igepon T Powder (Anionic)**
	28 Percent Active
	4 Grams
WATER SOFTENER	Soda Ash
	100 Grams Per Liter Solution
	150 Milliliters
ELECTROLYTE	Sodium Chloride
	100 Grams Per Liter Solution
	1 Liter
ADDITIONAL LIQUOR	8.0 Liters Distilled Water

*Manufactured by E. I. du Pont de Nemours and Company, Inc.

**Manufactured by General Aniline and Film Corp.

Table 12. Pressley Bundle Breaking Strengths of Cotton Specimens Before Blending

Test Number	Tenacity* (Grams per Tex)
1	47.32
2	54.45
3	51.40
4	49.56
5	50.85
6	46.68
7	53.83
8	45.36
9	51.24
10	46.53
11	50.40
12	50.43
13	46.69
14	45.90
15	48.29
16	46.71
17	54.59
18	45.31
19	44.69
20	45.36
21	43.50
22	51.68
23	52.71
24	47.54
25	46.18

Mean Value = 48.79 Grams per Tex

Standard Deviation = 3.22 Grams per Tex

Coefficient of Variation = 6.60 Percent

*At zero gauge length

Table 13. Pressley Bundle Breaking Strengths of Cotton Specimens After Blending

Test Number	Tenacity* (Grams per Tex)
1	52.50
2	51.44
3	51.79
4	48.14
5	50.57
6	49.03
7	49.24
8	50.66
9	50.59
10	51.81
11	50.63
12	50.98
13	51.06
14	51.67
15	51.30
16	51.06
17	49.30
18	50.86
19	49.40
20	48.08
21	49.81
22	51.24
23	51.48
24	51.78
25	51.64
Mean Value =	50.57 Grams per Tex
Standard Deviation =	1.12 Grams per Tex
Coefficient of Variation =	2.21 Percent

*At zero gauge length

Table 14. Fineness Measurements of Cotton Specimens Before Blending

Test Number	Fineness (Micrograms per Inch)
1	3.75
2	3.75
3	3.75
4	3.60
5	3.60
6	3.75
7	3.70
8	3.55
9	3.65
10	3.55
11	3.60
12	3.65
13	3.75
14	3.70
15	3.75
16	3.65
17	3.90
18	3.85
19	3.90
20	3.90
21	3.85
22	3.90
23	3.85
24	3.85
25	3.80

Mean Value = 3.74 Micrograms per Inch

Standard Deviation = .11 Micrograms per Inch

Coefficient of Variation = 3.04 Percent

Table 15. Fineness Measurements of Cotton Specimens After Blending

Test Number	Fineness (Micrograms per Inch)
1	3.80
2	3.80
3	3.75
4	3.65
5	3.65
6	3.60
7	3.65
8	3.65
9	3.60
10	3.70
11	3.75
12	3.70
13	3.75
14	3.75
15	3.80
16	3.75
17	3.70
18	3.80
19	3.75
20	3.70
21	4.00
22	3.85
23	3.90
24	3.85
25	3.90

Mean Value = 3.75 Micrograms per Inch

Standard Deviation = .09 Micrograms per Inch

Coefficient of Variation = 2.49 Percent

Table 16. Fibrograph Data for Cotton Specimens Before Blending

Test Number	66.7% Span Length (Inches)	50.0% Span Length (Inches)	2.5% Span Length (Inches)	Upper Quartile Length* (Inches)	Mean Length* (Inches)
1	.374	.529	1.245	1.231	1.015
2	.444	.595	1.285	1.380	1.136
3	.406	.567	1.291	1.320	1.098
4	.442	.594	1.295	1.380	1.140
5	.404	.556	1.261	1.299	1.067
6	.404	.550	1.271	1.311	1.052
7	.402	.552	1.258	1.288	1.058
8	.412	.560	1.275	1.322	1.076
9	.438	.579	1.290	1.392	1.115
10	.400	.551	1.268	1.287	1.065
11	.429	.580	1.278	1.334	1.099
12	.428	.592	1.296	1.320	1.128
13	.409	.557	1.264	1.287	1.076
14	.408	.563	1.184	1.232	1.077
15	.436	.597	1.320	1.353	1.150
16	.495	.637	1.302	1.488	1.206
17	.454	.610	1.300	1.379	1.168
18	.474	.609	1.058	1.313	1.218
19	.442	.582	1.042	1.236	1.148
20	.433	.587	1.141	1.243	1.133
21	.473	.616	1.287	1.428	1.178
22	.431	.583	1.267	1.322	1.127
23	.533	.670	1.335	1.598	1.263
24	.396	.540	1.249	1.277	1.047
25	.436	.580	1.139	1.264	1.107

*Estimated by graphical method.

Table 17. Fibrograph Data for Cotton Specimens After Blending

Test Number	66.7% Span Length (Inches)	50.0% Span Length (Inches)	2.5% Span Length (Inches)	Upper Quartile Length* (Inches)	Mean Length* (Inches)
1	.385	.524	1.227	1.254	1.028
2	.434	.560	.992	1.183	1.111
3	.444	.573	1.039	1.270	1.125
4	.424	.555	.995	1.196	1.103
5	.373	.508	1.036	1.109	.985
6	.427	.574	1.267	1.334	1.106
7	.428	.565	1.262	1.369	1.081
8	.418	.569	1.274	1.309	1.101
9	.563	.675	1.315	1.794	1.269
10	.417	.558	1.267	1.334	1.088
11	.443	.583	1.274	1.392	1.121
12	.409	.565	1.295	1.320	1.098
13	.451	.604	1.301	1.402	1.181
14	.445	.591	1.298	1.404	1.140
15	.443	.594	1.286	1.369	1.131
16	.409	.549	1.022	1.150	1.070
17	.452	.594	1.102	1.284	1.156
18	.462	.613	1.293	1.380	1.164
19	.504	.646	1.314	1.500	1.218
20	.471	.617	1.299	1.476	1.172
21	.473	.621	1.307	1.452	1.189
22	.460	.607	1.295	1.416	1.164
23	.473	.620	1.300	1.440	1.176
24	.420	.561	1.264	1.334	1.088
25	.404	.559	1.289	1.321	1.083

*Estimated by graphical method.

Table 18. Uniformity Ratios of Cotton Specimens Before Blending

Test Number	Uniformity Ratio
1	42.5
2	46.3
3	43.9
4	45.9
5	44.1
6	43.3
7	43.9
8	43.9
9	44.9
10	43.5
11	45.4
12	45.7
13	44.1
14	47.6
15	45.2
16	48.9
17	46.9
18	57.6
19	55.9
20	51.4
21	47.9
22	46.0
23	50.2
24	43.2
25	50.9

Table 19. Uniformity Ratios of Cotton Specimens After Blending

Test Number	Uniformity Ratio
1	42.7
2	56.5
3	55.1
4	55.8
5	49.0
6	45.3
7	44.8
8	44.7
9	51.3
10	44.0
11	45.8
12	43.6
13	46.4
14	45.5
15	46.2
16	53.7
17	53.9
18	47.4
19	49.2
20	47.5
21	47.5
22	46.9
23	47.7
24	44.4
25	43.4

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