AN ANALYSIS OF THE WINDING OF TEXTILE YARNS IN OPTIMUM PACKAGE FORM

by

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Textile Division, May 1957

Certified by ....

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Chairman, Departmental Committee
on Graduate Students

Textile Tech
Thesis 1957

Cambridge, Massachusetts
May 20, 1957

Professor Leicester F. Hamilton
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Sir:

In accordance with the requirements for the degree of Master of Science in Textile Technology, I hereby submit my thesis entitled, "An Analysis of the Winding of Textile Yarns in Optimum Package Form."

Respectfully submitted,

William J. Miles

ABSTRACT

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Submitted to the Department of Mechanical Engineering, Textile Division on May 20, 1957 in partial fulfillment of the requirements for the degree of Master of Science.

At many stages in textile yarn manufacturing it is desirable that the various yarn packages contain the maximum yardage possible in the most convenient package form available. Under these conditions, fewer machine stops, fewer knots in yarns and fabrics, and reduced labor time in package handling can be obtained.

This analysis was undertaken to investigate and analyze the winding of yarns in optium form. The procedure selected was the examination and evaluation of the bobbin as formed on the modern cotton spinning frame, this particular package being chosen because it is the first form of wind encountered in yarn manufacturing and its influence is therefore reflected in many of the following processes. The major factors which determine the physical dimensions and composition of a bobbin were defined as coils per inch of yarn that are wound, the tension of the yarn during winding, and, to a lesser degree, length of taper at the bobbin ends. The experimentation took the form of an attempt to obtain an optimum bobbin by investigating and maximizing the effects of coils per inch and traveler-induced yarn tension upon the yardage within a given volume, yardage being a major determinant of optimum wind.

It was shown that increasing the coils per inch from a low to a high percentage of the maximum coils possible increased the density of packing significantly within a given bobbin volume. It was therefore concluded that this procedure is one worth considering in the attempt to increase yarn length within the volumes of existing bobbins. Varying the traveler weights from the lightest possible to the heaviest also increased the density of packing significantly. However, this posed serious yarn breakage problems, and it was therefore concluded that this was not an advisable means of increasing yardage. The over-all conclusions were that the existing bobbins as used on cotton spinning frames can be wound in a more efficient form, and that this should be attempted prior to further continuing the trend to increasingly larger bobbins and rings on the spinning frame as is being done in current commercial attempts.

Thesis Supervisor: Stanley Backer
Title: Associate Professor of Mechanical Engineering

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The guidance and assistance of Professor Stanley Backer during the course of this investigation is deeply appreciated. His sincere interest in this project and his willingness to give his time unsparingly greatly aided the effort.

The invaluable suggestions of Professor E. R. Schwarz, Professor of Textile Technology, are also sincerely appreciated. Coming at crucial periods during this investigation, his recommendations and thought-provoking ideas removed many obstacles from the path of this analysis.

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INTRODUCTION

When textile yarns are first spun from natural or man-made fibers, it is necessary that these newly-formed lengths be rapidly collected and held in some convenient form or package while the twisting and winding is in progress on the spinning frame. This package must further serve to insure that these running lengths readily lend themselves to subsequent handling and processing. Each successive operation must, in turn, hold this yarn in some arrangement convenient for the manufacturing process at hand and must then place it in a form suitable for the succeeding stages. These forms are most often seen in the mills as the tapered bobbins found on spinning frames, as the cylindrical "cheeses" wound from bobbins on the automatic spoolers, as large, cylindrical warp beams used in the looms, and as the multitudes of cones upon which the synthetic yarns are often wound. Experience over the years has indicated that these forms most adequately meet handling and processing needs throughout the textile industry.

At many of these stages in textile yarn manufacturing it becomes very desirable that the various yarn packages contain the maximum yardage possible in the given package volume. Increased yardage on each package being processed is reflected in fewer machine stops, fewer knots in yarns and resulting fabrics, and less labor time spent in package handling. This represents a financial gain to the mill man, and is therefore of vital interest to him. But, as previously mentioned, each package must still remain convenient for the handling and treatment in the process under consideration and in the following phases. This package problem, therefore, is one of combining maximum yardage in the most efficient possible form. This optimum package, or optimum wind, is a problem that has long been present in textile industrial thinking, and one which no doubt will appear as long as yarn is spun and wound using present day techniques.

This thesis was undertaken to investigate the problems which arise when attempting to attain an optimum wind for a yarn package. The procedure selected was a careful evaluation of the bobbins as formed on the cotton spinning frame in order to study the factors which determined package form, dimensions and composition as the bobbins were being built. The bobbin was selected as the form to investigate because this is the first wind encountered during manufacturing, and its influence is therefore reflected in all subsequent procedures. This approach would show, it was believed, that maximum efficiency in the actions of the controlling factors could provide an optimum wind on the frame and could be used as a basis for investigation of other package forms containing yarns of different fibers.

CHAPTER II

BACKGROUND

The Ring Spinning Frame

Spinning textile yarns by means of ring spinning frames has been the standard method for well over one hundred years. A vast improvement over the Hargreaves spinning jenny and the Arkwright spinning machine, the ring frame was invented in 1828 and introduced in 1831.(1)* Subsequent improvements and adaptations have resulted in the machines used today.

In ring spinning methods, fibers are first drawn to a thin ribbon by action of three rolls revolving at different speeds. This ribbon is then twisted to a certain calculated number of turns per inch to impart necessary strength and desired yarn characteristics. The resulting yarn is then wound on wooden bobbins or paper tubes.

In the last twenty years or so, this winding process has come to be examined critically. Mill men, anxious to increase the amount of yarn on each bobbin, began investigating the possibility of obtaining larger packages on the spinning frame. To meet this real interest and demand, the textile machinery manufacturers now supply frames that hold larger bobbins than ever before and which boast continuing improvements of parts which function to wind the yarn in coils on the bobbins. Mills that are still running the older frames are now converting to large package spinning in order to decrease their costs in this highly

*Numbers in parentheses refer to the Bibliography.

competitive, present-day market. All in all, there is a great interest in this problem of placing more yarn on a bobbin, and improvements are eagerly awaited in the industry.

Although this problem is of more-than-routine interest to many textile concerns, it was noticed that there is a surprising dearth of information on the subject in the literature. Some articles did mention package improvement during spinning, but these mostly proved, upon investigation, to be brief descriptions of trial-and-error methods and rule-of-thumb techniques.[(2)]

Standard Packages on Ring Frames

There are three types of packages or, in textile terminology, winds, formed on spinning frames today. The type chosen depends upon what the particular concern deems appropriate, from its personal experience, for the immediate and end uses of its yarn. The winds differ in the lengths and placements of the coils, and indications are that different mills often champion different winds to serve the exact same purposes, nothing resembling a universal agreement existing among them.[(3)]

Warp Wind. This type of wind is used extensively for warp yarns that are to be wound onto larger packages and, subsequently, loom beams. The yarn on these bobbins is composed of coils arranged in gradually shortening traverses from inner to outer bobbin layers, and the completed package has a taper on both ends to prevent yarn "sloughing off" during handling. During the formation of these bobbins, the rate of traverse in both directions is generally the same.

Filling Wind. This type of packaging is used to wind bobbins of yarn in a form suitable for direct use in loom shuttles. The yarn is placed on the bobbins in fairly short traverses of constant length, each traverse being positioned slightly above the one preceding it. Common mill practice is to have the coils formed as the ring rail moves downward, with a rapid traverse then applying binder coils as the rail moves up to its new starting position.

Combination Wind. This type of wind, as the name implies, is a combination of the warp and filling winds. It utilizes the long traverses of the warp wind and moves them gradually upward in the manner of the filling wind. This practice insures that each layer is completely covered by each succeeding layer, and merits consideration in fine yarn mills where long periods between doffs permit grime to settle on the yarns. It is claimed that the yarn is prevented from tangling during unwinding at high speeds due to the difficulty of one coil mingling with a preceding or subsequent coil.[1]

Factors Influencing Yarn Package Building

The volume of a given bobbin of yarn and its form are dependent primarily upon the following:

1. The type of wind chosen.
2. The length of the yarn traverse on the bobbin barrel.
3. The shape and length of tapers at both ends.
4. The coils per inch in each traverse.
5. Tension during winding.
6. Bobbin height and ring diameter.

The major machine components influencing the size and shape of the packages are found on the builder motion. Located under the frame, this mechanism consists of a cam, driven through gearing from the drum shaft, and an arm pivoted near the floor. The builder cam runs in contact with a roll follower, and it is this builder cam that causes the builder arm to rise and fall. This builder arm, in turn, is connected by chains and levers to the lifter rods and ring rails, and causes the rail to rise and fall. The builder cam causes the traverse to be long or short, according to its shape and size. Warp cams are equal-sided, heart-shaped devices causing long traverses of the ring rail. Filling wind cams are generally three or four leaf, unequal-sided devices which cause short traverses and build a bobbin of superimposed cones of yarn. A combination wind ordinarily employs a warp cam with the builder adjusted for the filling wind.

The position of successive traverses during winding is regulated by the pick gear on the end of the builder arm. A pawl turns the pick gear a predetermined number of teeth to position the builder chain for the next traverse. The fewer the teeth that are picked, the less steep the taper on the bobbin ends. Taper has to be decided in the light of ring diameter available, bobbin diameter, height of traverse, and, most important of all, the impending handling and processing.

The coils per inch of traverse are called the "lay" in textile terminology, and lay is referred to as being "close" or "open" in general mill discussion. A close lay in which each coil would be touching but not forcing against the next has always been considered the optimum lay.[3]

The number of coils per inch under these circumstances depends upon the yarn diameter, and this value in inches is obtained from the formula:

$$.9 \sqrt{\frac{1}{\text{yards per lb.}}}$$

developed by Ashenhurst.[1]

Tension during winding affects the amount of yarn contained on a given bobbin by being able to appreciably alter the compactness of the wind. Tension is one of the major problems in ring spinning, varying considerably as the bobbin is being built. Bobbin diameter, traveler weight, traveler-ring interaction, spindle speed, ring diameter and bobbin length act in various and varying combinations to cause fluctuations in yarn tension during winding. The woolen and worsted industries, using larger packages and coarser yarns than are found in the cotton mills, have coped with this variable tension problem by using frames with variable spindle speeds, a practice which seems to produce satisfactory results for them.[7]

CHAPTER III

APPROACH AND PRELIMINARY INVESTIGATIONS

Approach

The attempt to increase the yardage on a bobbin has, as previously stated, come to the fore in the past twenty or so years, precipitating the development of what is termed "large package spinning." This attempt to achieve greater yardage has placed primary emphasis on increased bobbin length and greater ring diameter. Little attention apparently has been given attempts to increase yardage in the volumes encompassed by existing bobbins. The standard textile mill rules-of-thumb which have dictated, over the years, the limits of coils per inch, traveler weight, and taper, determining factors in bobbin formation, have apparently been accepted without too much question as invariable elements.

From considering the mechanical method by which yarns are wound, it was decided early in this investigation that the logical approach to optimum wind would be to first attempt attainment of maximum yardage within the existing bobbin volumes. This, it was believed, should definitely be done prior to any experiments with bobbin length and ring diameter, for these latter methods would not permit fuller utilization of existing equipment. Taper at the bobbin ends was recognized as another major determinant of optimum wind, but one which should receive secondary emphasis at this particular time.

One of the factors most influencing the yardage per given volume has long been accepted by textile mill men as coils per inch.[3]

There is general agreement that an ideal packing of yarn within a bobbin would be obtained when each coil is placed immediately adjacent to the coils preceding and following it.(3) Coupled with this, traveler weight, by being capable of varying tension, becomes another appreciable influence on the density of packing and the total bobbin yardage.

In the light of these considerations, the decision was formed to begin this investigation with studies of the effects of coil per inch and traveler tension variations upon the packing of yarn on a bobbin. With this approach, the contributions of these two factors to overall yardage could more accurately be assessed. The conclusions could then be drawn concerning the significance of these determinants under practical mill operating conditions.

The Need for a Technique

With this approach to the problem in mind, it became essential that some method be devised which would accurately present the packing in any given volume and, more important, permit a measurement of change in packing as a result of experimentation. The ideal situation for this purpose, it was early seen, would be to view the yarns in cross section as they lay in a coiled state, under tension, around the bobbin circumference. All effort was therefore directed toward acquiring this method of analysis.

Development of a Technique

It has been the practice in the Textile Division of the Massachusetts Institute of Technology to view small fabric specimens in cross section by first embedding the samples in a clear plastic. In this method, the fabric was positioned in a small cardboard box, a polyester resin was poured in, and the specimen was heated for about 10 minutes at 80°C. A hard plastic formed from this resin, firmly holding the fabric in the desired configuration. A cut was then made at any chosen point, the cut surface faces were polished to a high smoothness, and the internal structure was then effectively viewed under a microscope.

This technique, it was decided, would provide exactly what was desired for bobbin cross sectioning if the method could be successfully applied to these larger specimens. The procedure was therefore modified and attempted in the following manner:

The polyester resin, which was "Laminac, Type 4116", an American Cyanamid Company product, was mixed with "Lupersol", an oxidizing material composed of 60% methyl ethyl ketone peroxide in dimethyl phthalate. The proportions were 99cc. of "Laminac" to 1cc. of "Lupersol", and the mixture was thoroughly stirred for a 10 minute period. A number of sample bobbins had been prepared, previous to this mixing of the resin, by cutting the bobbins at right angles to the longitudinal axes to form small cylinders about 1½ inches long. Prior to making the cuts, glue and masking tape had been applied to the circumferences at the points of cutting in order to eliminate any fraying or unwinding of the yarn layers. These cylinders were then placed in small cardboard boxes measuring somewhat larger than the bobbin sections, and the liquid mixture was poured in until the boxes were about half full. This resin mixture was swirled and washed back and forth for a 5 minute period to facilitate penetration of the yarn layers. The samples were then heated in the oven at 80°C. for about 20 minutes and set aside to cool for about 1 hour. Each specimen was then cut longitudinally into quadrants, and the rough surfaces of the lower quadrants, the surfaces containing the yarn sections to be viewed, were carefully smoothed with a fine sandpaper. These surfaces were then further smoothed with succeedingly finer emery paper of 1/0, 2/0, and 3/0 grades, care being taken to obtain as plane a surface as possible. A high polish was then achieved by placing the samples on the revolving "wet wheels" used for the preparation of metallographic specimens. Approximately 15 minutes of this procedure, using the coarsest wheel followed by the intermediate wheel, was sufficient to impart an extremely high gloss to the surfaces. Care was taken to thoroughly cleanse each surface after the polishing in order to remove the soapy solutions used on the wheels.

This procedure proved to be highly successful on the experimental specimens. The surfaces, when viewed under the microscope, clearly showed the yarns in cross section as desired, illustrating well their spacing along the bobbin barrel and throughout the cross sectional area. With this method as a weapon, it was then possible and practical to plan further work which could be evaluated successfully by this means.

Measurement and Expression of Yarn Packing

Establishment of this embedding technique in turn necessitated the application of a method to accurately measure and express the density of yarn packing in any given cross sectional area. The method arrived at consisted of expressing the density of packing within this given cross sectional area in terms of a packing factor, a ratio between the amount of a given area which the yarn cross sections filled and that total area.

To find the packing factor for a section under consideration, the cross sections of all yarns in a selected rectangular area were drawn on paper by means of a camera lucida mounted on a microscope. The ratio of the area covered by the sections to the area of the given rectangle which encompassed them was equal to the packing factor, related to the base 1. Computation of the values was effected by cutting out the rectangle and weighing it, cutting out the sections and weighing all of them, and dividing the latter by the former weight. Experimentation showed that a rectangle measuring 5 inches by 4 inches fitted well into the field of view provided by a 10x ocular and a 32 mm. objective. Drawings thus made held approximately 70 cross sections in the rectangle, illustrating a magnification of about 60 diameters. Five drawings were averaged for each packing factor determination in order to insure a representative value.

CHAPTER IV

VARIATION OF COILS PER INCH

Equipment

The spinning frame that was used to spin the yarn for this initial experiment was a Whitin Model F-5 laboratory model located in the Slater Laboratory at the Massachusetts Institute of Technology. It was set up using standard mill procedures as given in the American Cotton Handbook in order to approximate industrial practice. The particulars are as follows:

Yarn. This was 20/1 cotton yarn formed from 1.00 hank roving.

Draft and Draft Gear. The draft required for a 20/1 yarn is:

$$\frac{20(\text{yarn})}{1.00(\text{hank})} = 20 \text{ draft}$$

Allowance for twist contraction, however, actually requires that a finer count be spun. Using 10% as an estimated contraction:

$$\frac{20(\text{yarn})}{.90} = 22 \text{ yarn}$$

Then, since a 22/1 yarn is actually required:

$$\frac{22(\text{yarn})}{1.00(\text{hank})} = 22 \text{ draft}$$

The draft change gear is then found from:

$$\frac{739(\text{draft constant for the frame})}{\text{draft desired}}$$

$$\frac{739}{22} = 34 \text{ teeth}$$

This draft constant, other constants, and many frame particulars were established by Professor Peter F. Grishin of the Textile Division at the Massachusetts Institute of Technology.

Twist and Twist Gear. Twist required for this yarn:

$$4.25 \sqrt{\text{counts}} = 19 \text{ turns per inch}$$

The twist multiplier of 4.25 was selected due to the length of the cotton used.

The twist gear is then found from:

$$\frac{857 \text{ (twist constant for the frame)}}{\text{turns per inch}}$$

$$\frac{857}{19} = 45 \text{ teeth}$$

Spindle Speed. 8000 r.p.m.

Ring Diameter. $2\frac{1}{2}$ inches.

Wind. A combination wind was used to form all packages.

Procedure

This test series consisted of coil per inch variations within the maximum range possible on the frame and evaluation of the resulting packing for each variation. With 20/1 yarn, the maximum number of coils per inch along a bobbin is:

$$.9 \sqrt{\text{yards per lb.}} = .9 \sqrt{(20)(840)} = 117 \text{ coils per inch}$$

Experimentation showed that it was impossible to vary the coils up to this figure due to gearing limitations. By altering the ratio between the lay change gear and its driver, however, a maximum range of from 10 to 50 coils per inch was established for the upward traverses. (The frame functions to place 1/2 the number of coils per inch on the downward traverses.) These values of 10 and 50, and intermediate values were established by experimental observations of the following combinations:

TABLE I

GEARING COMBINATIONS FOR COIL PER INCH RANGE

Lay Change Gear	Lay Driver	Coils per Inch
60	30	10
45	30	13
60	50	18
45	50	24
60	78	28
44	78	34
40	78	44
30	78	50

Sets of 5 bobbins were wound at each coil per inch variation. The running time for each set was chosen as 2 hours, a period sufficiently long for packing representative of a full bobbin to be formed. A No. 4 traveler, weighing approximately .085 grams, was selected to give high enough tension to insure good running. After each 2 hour run, the ring rail was wound to the lowest starting position in order to eliminate any variations which might have been caused by successively higher ring rail positions as spinning progressed. In addition, the same spindles were used for each succeeding set, and the bobbins were labeled according to the spindles they came from. This was done in order to continue any peculiarities of a particular spindle throughout the entire series, eliminating a possible error source.

One bobbin wound on the same spindle was then selected from each set and was embedded and polished. The camera lucida drawings were made in the manner previously described, and packing factor was computed to illustrate the trend caused by the coil per inch variations.

Data

Tables II through IX list the information used in the calculation of packing factor for this coil variation.

The relationship of coils per inch to packing factor is plotted in Figure 1.

Figures 2, 3, and 4 are photomicrographs of bobbin cross sections at 10, 24, and 50 coils per inch, respectively.

Observations

Varying the coils per inch from 10 to 50 increased the density of packing perceptibly. This verified the belief that by more carefully positioning a greater of coils along a given bobbin length it would be possible to place more yarn in the overall bobbin volume. It was surprising that a packing factor as high as .73 was obtained from the 10 coils per inch traverses, for current and past literature led one to believe that packing would be considerably less.[3] However, the yarns in this case showed a definite tendency to fall into whatever spaces existed, thereby approximating fairly effectively a traverse which contained a greater number of initial coils per inch.

TABLE II

10 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.925	.685	.745
2	.967	.702	.726
3	.930	.663	.714
4	.954	.675	.719
5	.961	.711	.740
		AVERAGE	.73

TABLE III

13 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.931	.682	.717
2	.945	.707	.749
3	.942	.674	.715
4	.933	.702	.754
5	.928	.722	.778
		AVERAGE	.74

TABLE IV

18 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.922	.669	.725
2	.932	.632	.678
3	.936	.689	.736
4	.948	.687	.726
5	.933	.734	.787
		AVERAGE	.73

TABLE V

24 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.933	.730	.783
2	.955	.724	.769
3	.941	.721	.767
4	.945	.689	.730
5	.924	.734	.794
		AVERAGE	.77

TABLE VI

28 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.934	.693	.742
2	.964	.767	.796
3	.956	.714	.746
4	.963	.768	.797
5	.945	.727	.770
		AVERAGE	.77

TABLE VII

34 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.781	.612	.783
2	.780	.615	.789
3	.780	.605	.775
4	.796	.607	.763
5	.735	.575	.735
		AVERAGE	.77

TABLE VIII

44 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.777	.639	.821
2	.784	.615	.785
3	.784	.621	.793
4	.785	.601	.766
5	.804	.648	.806
		AVERAGE	.79

TABLE IX

50 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.782	.617	.790
2	.793	.608	.766
3	.803	.641	.800
4	.797	.640	.803
5	.790	.637	.807
		AVERAGE	.79

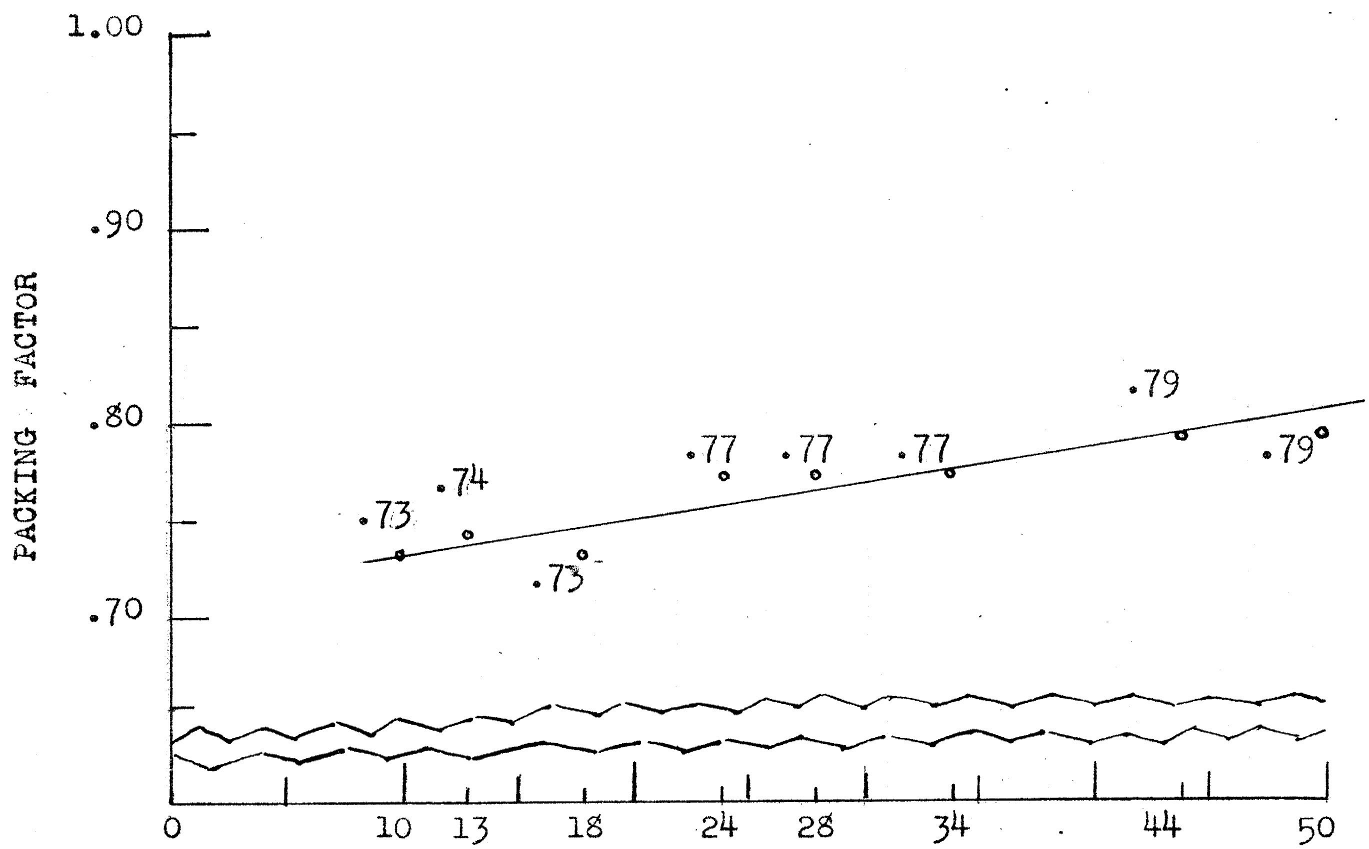

FIGURE 1

VARIATION OF PACKING FACTOR WITH COILS PER INCH

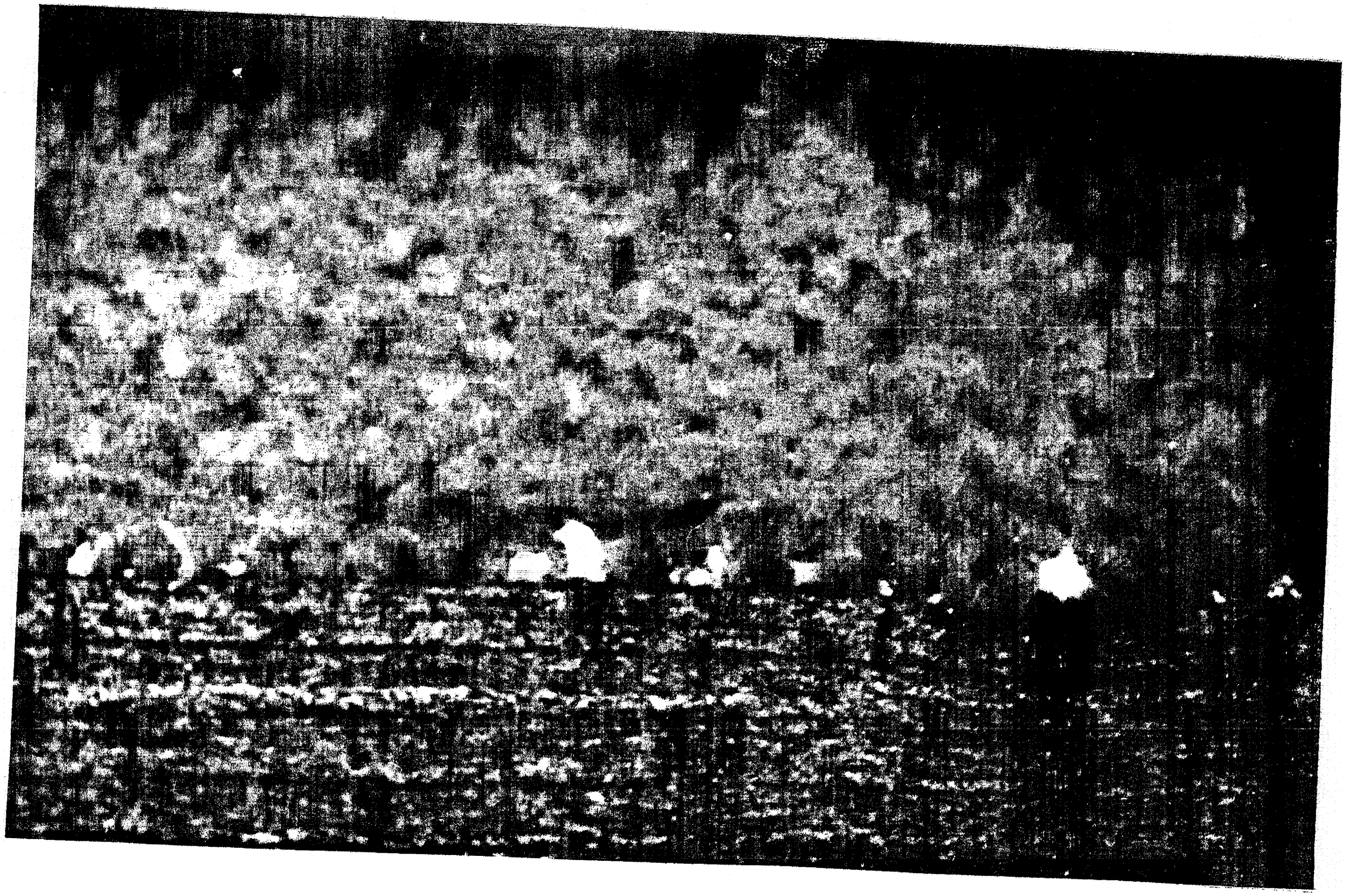

FIGURE 2

CROSS SECTION OF BOBBIN WOUND WITH 10 COILS PER INCH

MAGNIFICATION APPROXIMATELY 30 DIAMETERS

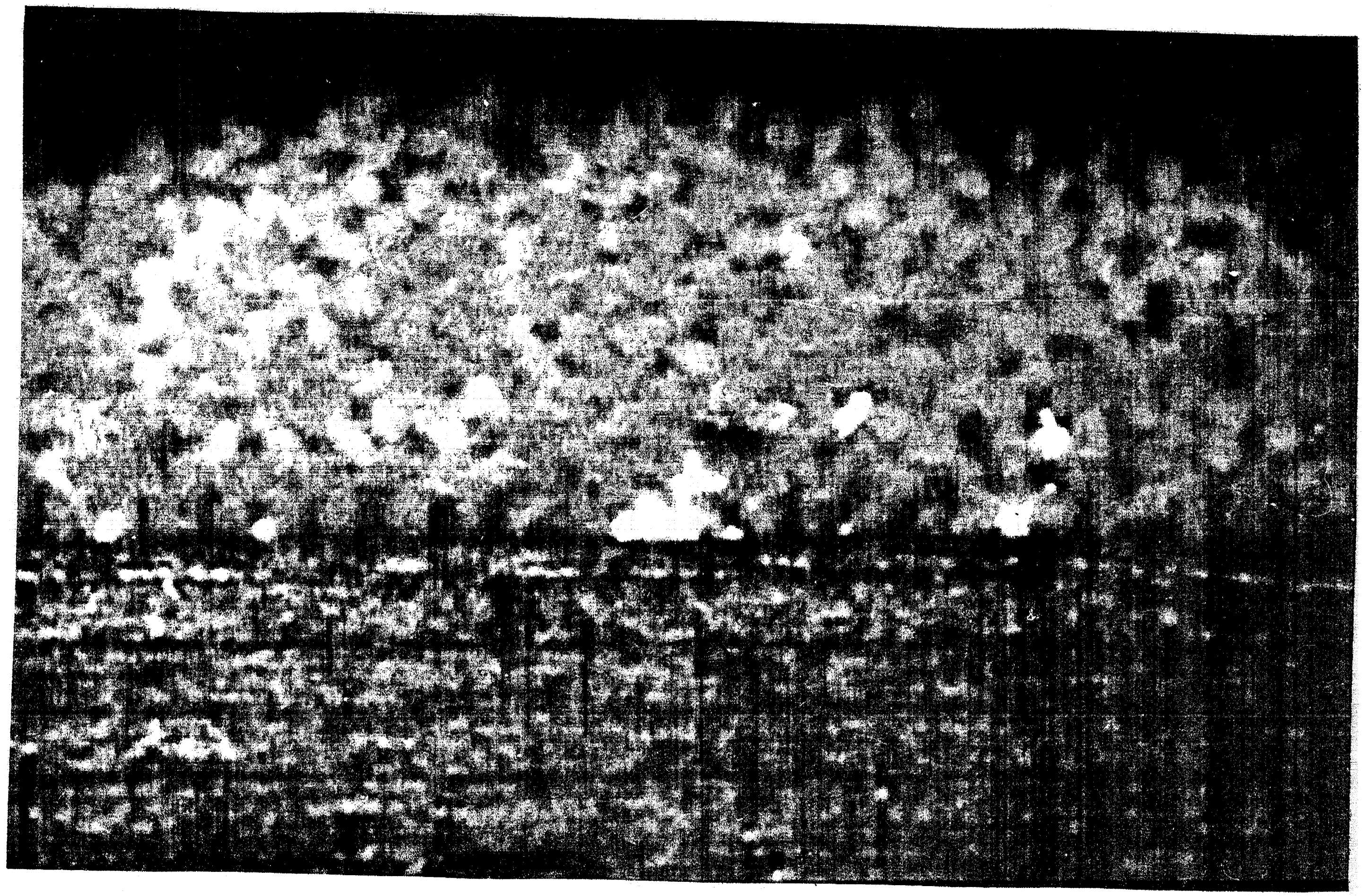

FIGURE 3

CROSS SECTION OF BOBBIN WOUND WITH 24 COILS PER INCH

MAGNIFICATION APPROXIMATELY 30 DIAMETERS

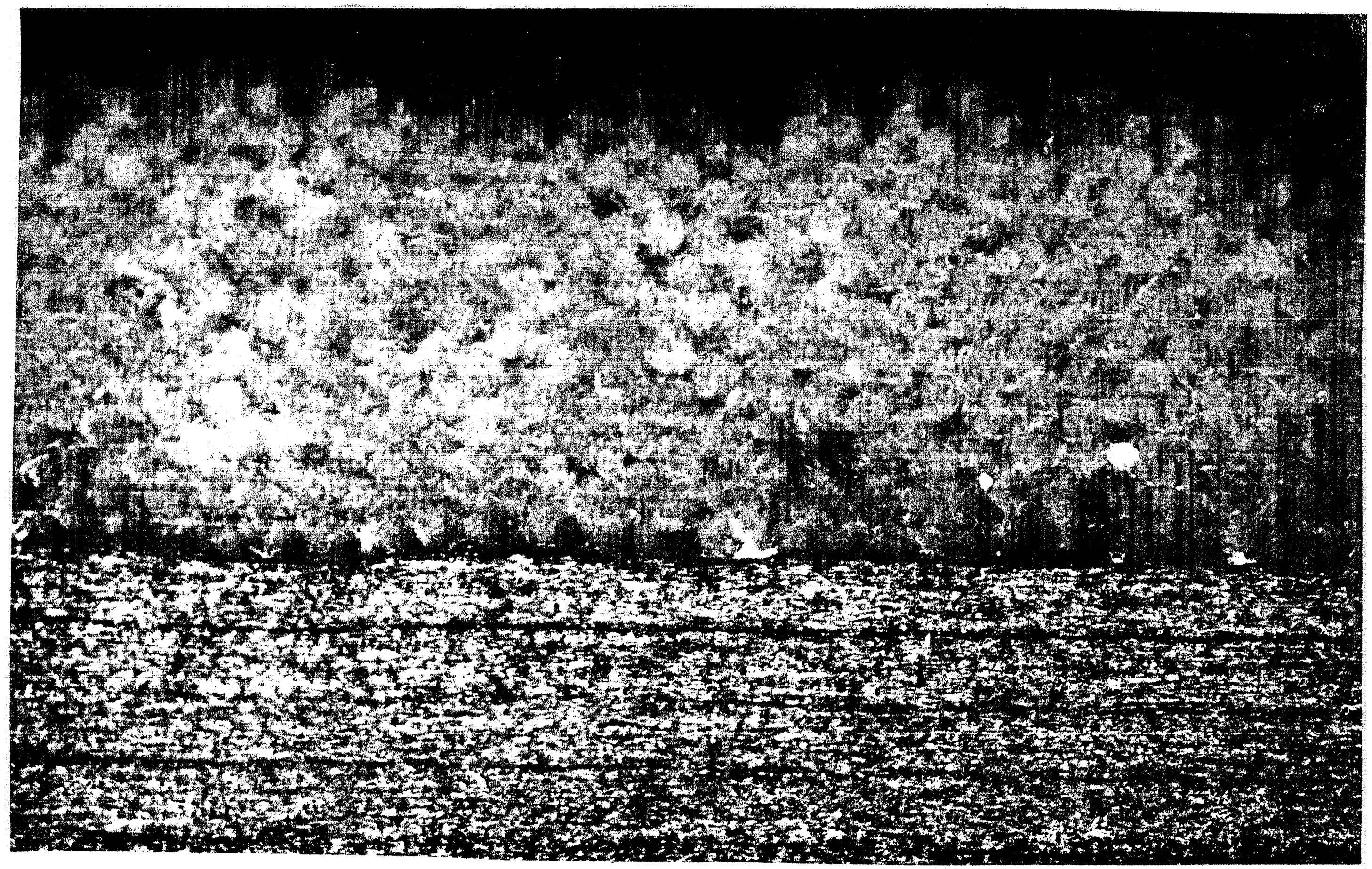

FIGURE 4

CROSS SECTION OF BOBBIN WOUND WITH 50 COILS PER INCH

MAGNIFICATION APPROXIMATELY 30 DIAMETERS

CHAPTER V

STUDY OF THE INITIAL TRAVERSES

Approach

Although the preceding experiment produced a definite packing factor increase as the coils per inch were increased, the range covered was not as great as was expected. This indicated that a study of how each traverse of yarn was positioned in relation to the bobbin barrel and to preceding and succeeding coils might prove of value to the study. The method decided upon was an examination of the placing of the initial 10 traverses upon the bobbin barrel, experimentation having shown that about 10 traverses covered the barrel surface even at a low number of coils per inch. The examination of cross sections showing, successively, 1 through 10 layers, it was believed, would provide a clear picture of how these initial coils determined the future packing of the bobbin.

To further clarify the study, it was decided that an attempt would be made to stain the yarns of each traverse if possible. This practice would then indicate exactly which traverse placed a given yarn in the particular position it occupied, thereby contributing additional information to the bobbin building procedure.

To attain this result, a device was made which would permit yarns to be colored with ink as they were in the process of being spun. Ink was chosen due to its quick drying properties, a necessary characteristic for a procedure such as this. The apparatus, shown in Figure 5, consisted of 5 light wooden wheels, mounted on a light metal shaft, and suspended over a plastic tray containing 5 shallow compartments. This

FIGURE 5

YARN STAINING APPARATUS IN POSITION ON THREADBOARD device measured about 9 inches in length and 2 inches in width. The face of each wheel was covered with a thin neoprene sheet 1/2 inch wide. Once ink was poured into each compartment, the wheels were turned by means of the shaft handle, continually wetting the neoprene surfaces. With this device it was then possible to stain a given traverse of yarn by holding this mechanism between the front rolls and the thread guide of the spinning frame, permitting the yarn to lightly contact the faces of selected wheels. Turning of the shaft caused a wet surface to be continually presented to the rapidly passing yarn, enabling a thorough coloring to be imparted. The simplicity of the apparatus also permitted it to be readily shifted to present a differently colored wheel to the yarn as each new traverse began.

Procedure

Using this approach, 10 bobbins were spun with stained yarn layers, the color being changed for each traverse. The frame was regulated to wind 24 coils per inch, an open lay chosen arbitrarily. The first traverse was wound on the bobbin as the ring rail was rising, and this layer was of white yarn. The second traverse was wound as the rail descended, and this yarn was colored black. The next traverse, upward, was stained red, and the fourth was colored green. Lack of additional colors then necessitated repeating this color scheme.

In this manner, 1 through 10 bobbins containing 1 through 10 layers, respectively, were spun. These were embedded, cross sectioned, and polished using the techniques earlier described. The sections were then carefully examined under the microscope and camera lucida drawings were made.

Figures 6 through 15 show segments of these sections as they appeared under the microscope, the yarns being magnified approximately 60 diameters. The letter within each yarn cross section indicates the color of that particular yarn.

Observations

Section 1 (Figure 6). This section held a single layer of white yarn.

The grooves placed every 1/4 inch along the bobbin barrel circumference showed a marked tendency to group 3 coils at these points, causing an uneven spacing of this first layer.

Section 2 (Figure 7). Two traverses were wound on this surface, the initial layer being white, the second being black.

The black yarn fell in readily alongside the white. The coils per inch averaged 31 by count along the bobbin surface.

Section 3 (Figure 8). The order of traverses was white, black, and red.

An occasional black or red yarn fell on the preceding coil, but the majority found space on the barrel surface. The 1/4 inch grooves, although they held 3 coils in the first traverse, did not seem to influence these next two layers. The coils per inch by count along the bobbin rose to 52 after this third traverse was applied.

Section 4 (Figure 9). The order of traverses was white, black, red, and green.

There was a noticeable placing of these latter green coils upon the preceding white, black, or red yarns, primarily at the 1/4 inch grooves or recesses. The coils per inch on the barrel surface numbered 60 once this layer was applied.

Section 5 (Figure 10). The order of traverses was white, black, red, green and white.

Clustering of yarns at the grooves was noticeable again, but a large number of yarns filled in some of the space along the bobbin surface. The coils per inch, by count, were raised to 78 along the inner layer with the addition of these yarns.

Section 6 (Figure 11). The order of traverses for this bobbin was white, black, red, green, white, and black.

Yarns began to pack in double layers at points other than the grooves for the first time. Visual count showed the coils per inch to number 86.

Section 7 (Figure 12). The order of colored traverses for this bobbin was white, black, red, green, white, black, and red.

Considerable double packing was seen at different locations, no preference being given the 1/4 inch ridges. Coils per inch along the inner surface numbered 87 by count.

Section 8 (Figure 13). The order of the colored traverses here was white, black, red, green, white, black, red, and green, two color repeats.

This section resembled the preceding section, exhibiting considerable double layer packing. Coils per inch numbered 87 once again.

Section 9 (Figure 14). Order of the traverses was white, black, red, green, white, black, red, green, and white.

Multiple layer packing began in earnest here although a few spaces existed along the surface where a yarn might have fitted in. The coils per inch along this surface numbered 93.

Section 10 (Figure 15). The order of traverses was white, black, red, green, white, black, red, green, white, and black.

Few spaces large enough to hold a yarn cross section were visible along the barrel, and double packing was the rule. The coils along the bobbin, though close, were not touching, numbering 93 per inch by count.

This series showed the tendency of the coils to fill the existing spaces extremely well along the bobbin surface. Although the frame was set for 24 coils per inch, these 24 coils of the initial traverse were rapidly raised in number to 93 as spinning progressed. This illustrates why the lower numbers of coils per inch do not act to reduce packing to the extent which might be expected.

Coloring each yarn traverse proved to be highly effective for the study of the first four traverses. After that point, however, no additional colors were obtained which could be differentiated under the microscope. Pronounced visibility of colors was required, and shadings of these inks which were used, and others, could not meet this requirement. Therefore, after the 4th traverse, it could not be stated with any degree of certainty which traverse a particular coil was from.

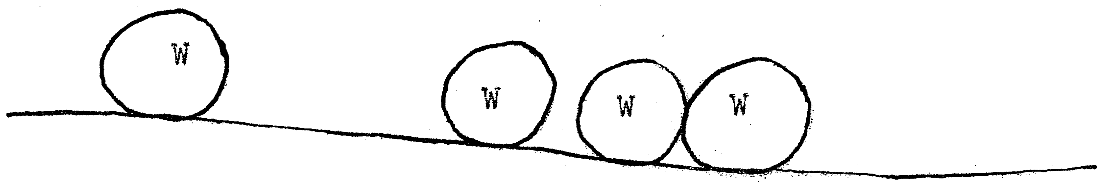

FIGURE 6 *

ONE TRAVERSE

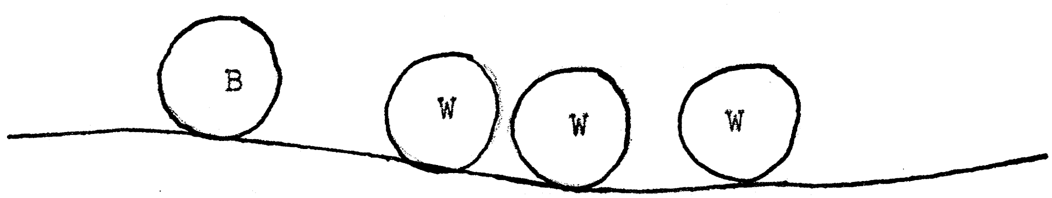

FIGURE 7

TWO TRAVERSES

* Figures 6 - 15 are at 60 diameters magnification. Letters refer to colors of cross sections, indicating white, black, red, and green.

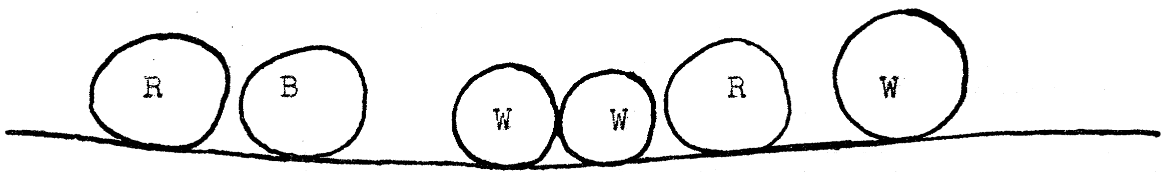

FIGURE 8

THREE TRAVERSES

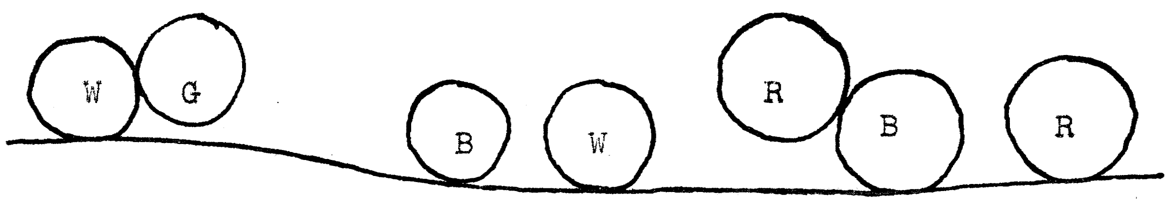

FIGURE 9

FOUR TRAVERSES

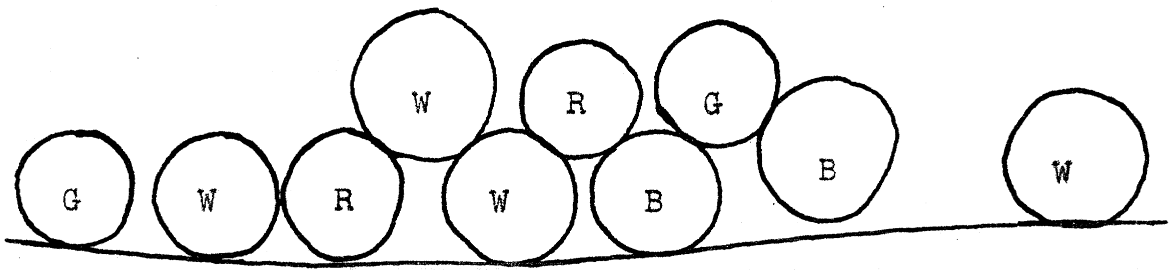

FIGURE 10

FIVE TRAVERSES

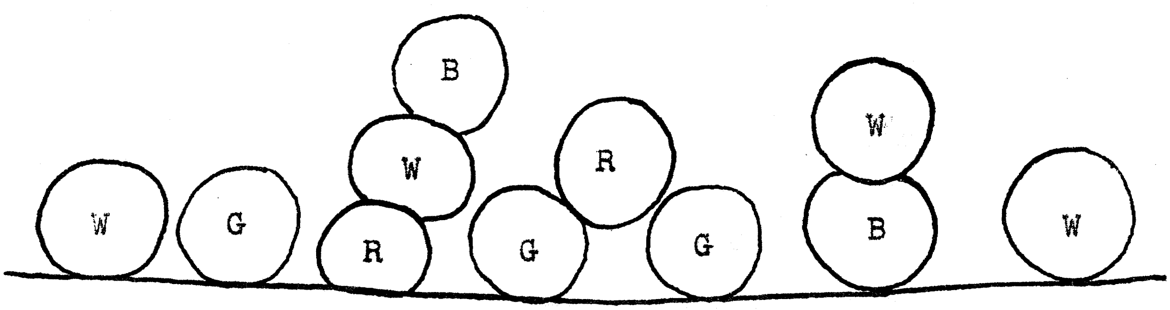

FIGURE 11

SIX TRAVERSES

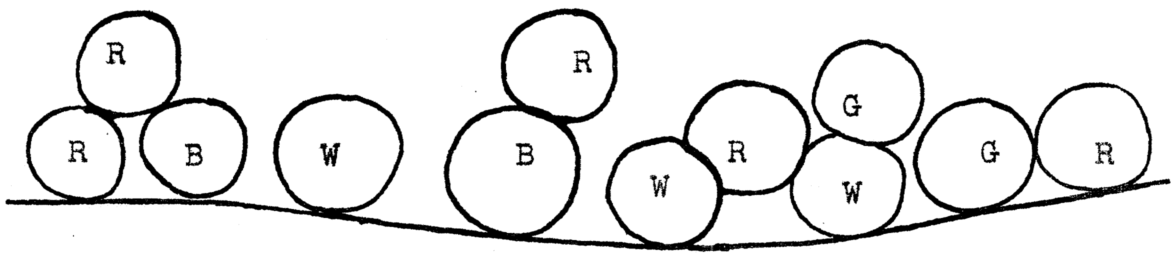

FIGURE 12

SEVEN TRAVERSES

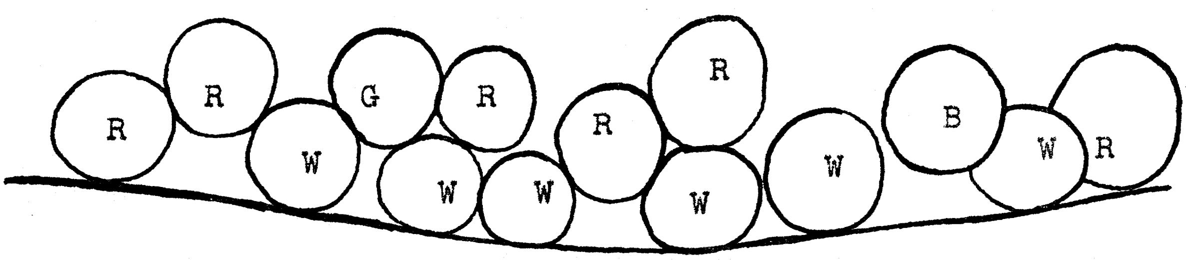

FIGURE 13

EIGHT TRAVERSES

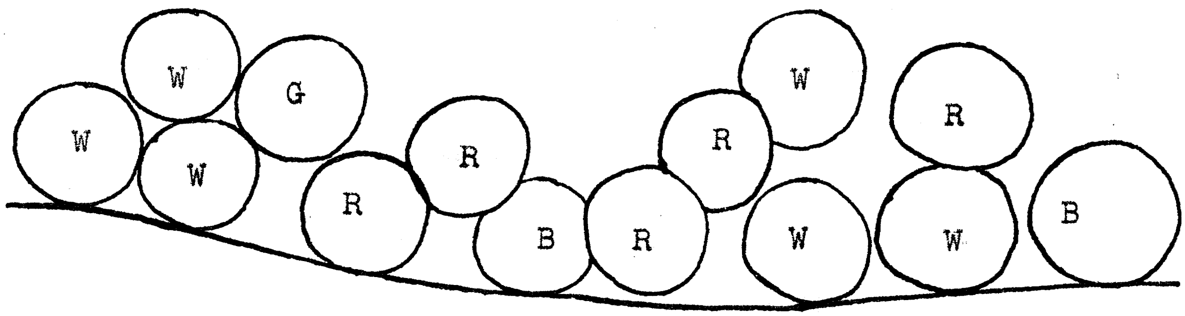

FIGURE 14

NINE TRAVERSES

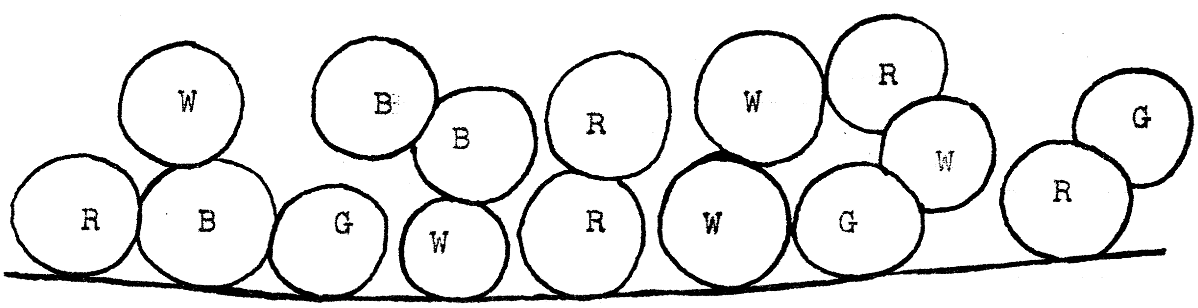

FIGURE 15

TEN TRAVERSES

CHAPTER VI

THE EFFECTS OF INCREASED TRAVELER WEIGHT

Procedure

The effects of traveler-induced tension increases in the yarn being wound was the next consideration in this investigation of optimum wind. To obtain these data, the spinning frame was adjusted as for the coil per inch experiments, with frame speed at 8000 r.p.m., the yarn remaining a 20/1 cotton, and with the coils per inch set for 50. The lightest and heaviest travelers with which it was possible to spin without balloon collapse were then experimentally determined, and these were taken as the limiting traveler values. Two intermediate values were also taken in order to provide a more complete picture of the effects within these extremes of traveler weight. The travelers selected were the standard Victor travelers, and these four, using mill designations, were a No. 12/0, weighing about .024 grams; a No. 3/0, weighing about .052 grams; a No. 2, weighing about .072 grams; and a No. 6, weighing approximately .11 grams.

With these four travelers on the rings, four bobbins of 20/1 yarn were spun, with a 2 hour period established as the running time. The bobbins thus prepared were then embedded and sectioned using the technique developed. Camera lucida drawings were then made and utilized to compute the average packing factors for each bobbin as was done before.

Data

Tables X through XIII contain information used in the packing factor calculations.

The relationship of packing factor to increased traveler weight, other conditions remaining constant, is plotted in Figure 16. It was originally intended that the theoretical yarn tension for each traveler value would be computed and included along with these traveler weights. Doing this, however, would necessitate the taking of a large number of experimental balloon diameter measurements and the establishment of the value of the coefficient of friction existing between the travelers and the rings. Unless these values could be more carefully determined than time herein would permit, the results could not be considered to be more than a rough indication.

Figures 17, 18, and 19 are photomicrographs of bobbin cross sections where the No. 12/0, the No. 2, and the No. 6 travelers, respectively, were used.

Observations

The packing factor range for this experiment extended from .76 to .84, showing that a substantial increase in density of bobbin packing can be obtained in this manner. However, this is of academic interest primarily, for large traveler weight increases alter tension much too drastically, tension already being a serious problem in spinning. This problem is further commented on in a following chapter devoted to an interpretation of findings.

TABLE X

NO. 12/0 TRAVELER

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.728	.591	.756
2	.781	.595	.761
3	.780	.625	.800
4	.775	.586	.756
5	.781	.585	.750
		AVERAGE	.76

TABLE XI

NO. 3/0 TRAVELER

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.784	.604	.771
2	.781	.590	.764
3	.803	.624	.777
4	.805	.624	.775
5	.776	.616	.794
		AVERAGE	.78

TABLE XII

NO. 2 TRAVELER

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.798	.622	.780
2	.800	.643	.804
3	.780	.633	.811
4	.803	.671	.836
5	.776	.630	.811
		AVERAGE	.81

TABLE XIII

NO. 6 TRAVELER

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.783	.645	.824
2	.788	.661	.840
3	.794	.635	.800
4	.797	.683	.856
5	.775	.663	.855
		AVERAGE	.84

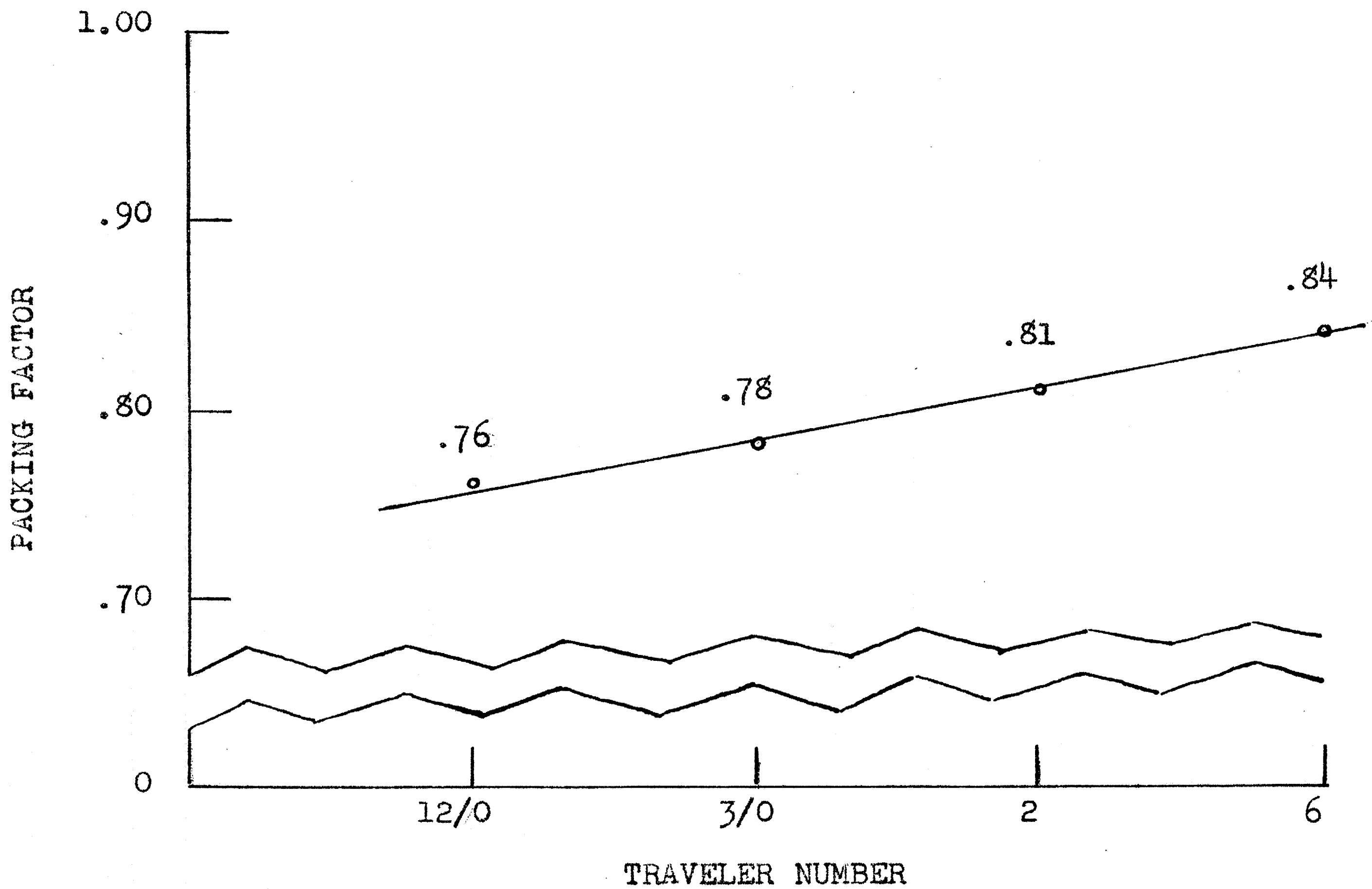

FIGURE 16

VARIATION OF PACKING FACTOR WITH TRAVELER TENSION

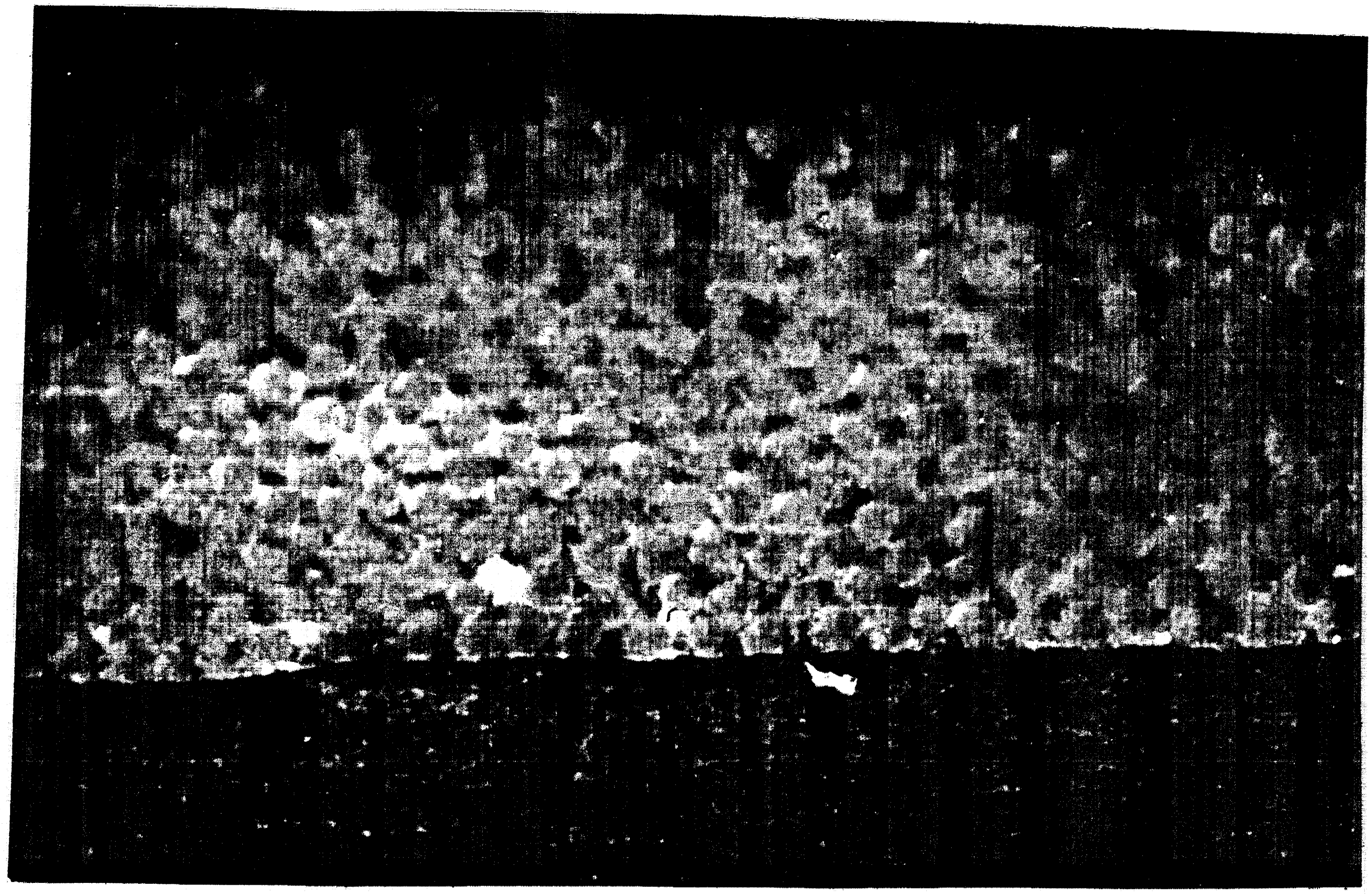

FIGURE 17

CROSS SECTION OF BOBBIN WOUND WITH 12/0 TRAVELER

MAGNIFICATION APPROXIMATELY 30 DIAMETERS

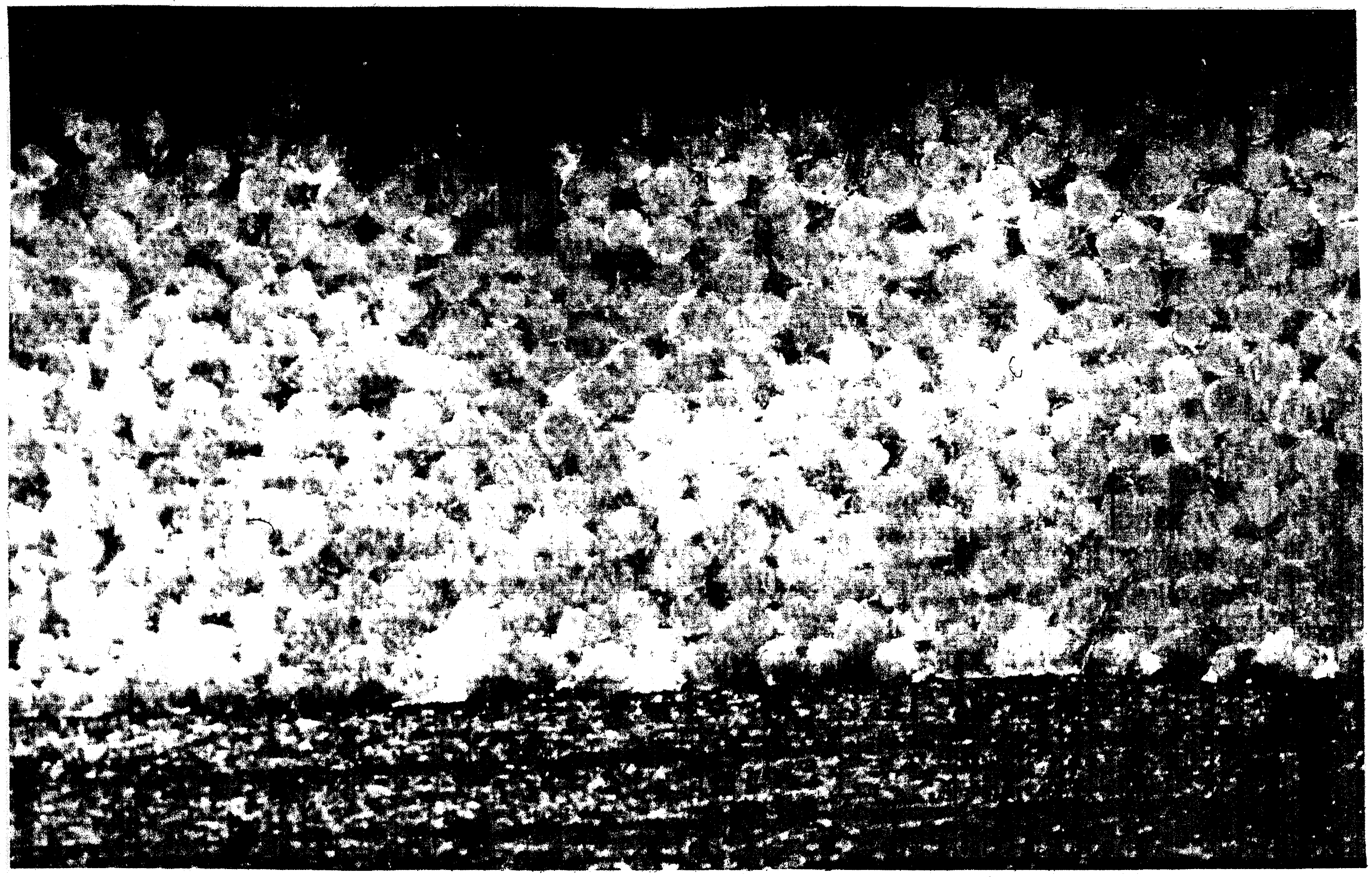

FIGURE 18

CROSS SECTION OF BOBBIN WOUND WITH NO.2 TRAVELER

MAGNIFICATION APPROXIMATELY 30 DIAMETERS

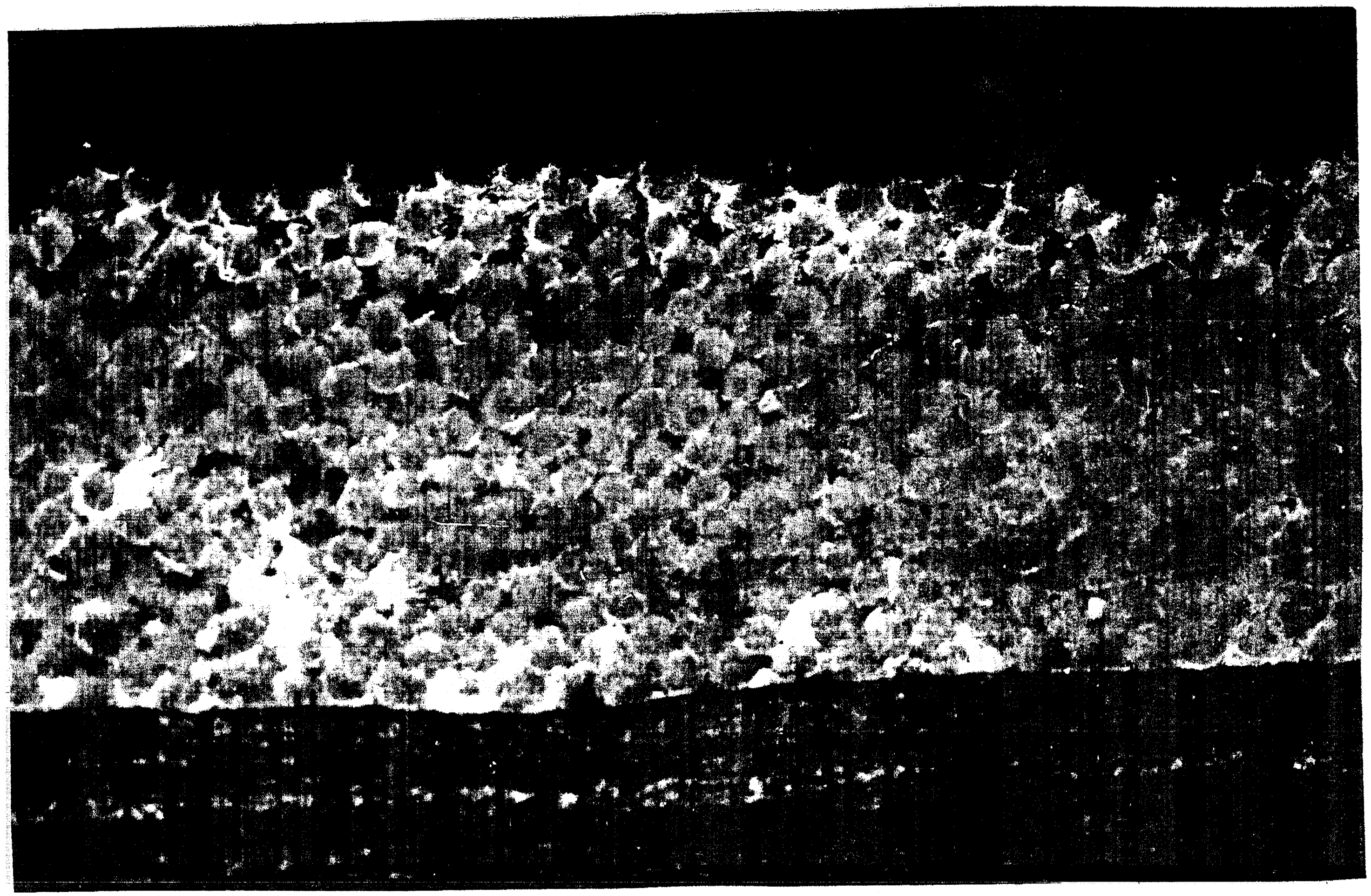

FIGURE 19

CROSS SECTION OF BOBBIN WOUND WITH NO. 6 TRAVELER

MAGNIFICATION APPROXIMATELY 30 DIAMETERS

CHAPTER VII

VARYING COILS PER INCH WITH A COARSE YARN

Reason

The various combinations of lay gears and lay driver gears available on the spinning frame permitted a range of from 10 to 50 coils per inch to be placed on the bobbins. In the first investigation of coil per inch increases using 20/1 yarn, this upper limit of 50 coils provided slightly less than 43% of the maximum number of yarns that could be actually placed along 1 inch of bobbin length. The desire to examine the packing over a range where the upper limit more nearly approached the maximum prompted this investigation. Since the frame was mechanically limited, the yarn was the factor which had to be varied to approach this condition.

Equipment

To conduct these coil per inch variations, the particulars for the spinning frame were as follows:

Yarn. An 8/1 cotton was chosen, this being spun from the 1.00 hank roving doubled to form .50 hank. This 8/1 yarn gave a maximum of

$$.9\ \sqrt{(8)\ (840)}\ =\ 74 \text{ coils per inch}$$

The frame therefore provided $\frac{50}{74} = 67.5\%$ of the maximum number of coils per inch possible when it was adjusted to wind 50.

Draft and Draft Gear. The draft required for this yarn is:

$$\frac{8(\text{yarn})}{.50(\text{hank})} = 16$$

Assuming that a 10% allowance for twist contraction is made:

$$\frac{8}{.90} = 8.90 \text{ before contraction}$$

Then, actual draft is: $\frac{8.90}{.50} = 17.80$

This requires a draft gear of: $\frac{739}{17.80} = 42$ teeth

Twist and Twist Gear. The twist required is:

$$4.25\sqrt{8} = 12 \text{ turns per inch}$$

The maximum available twist gear, however, is a 60 tooth gear. This provides:

$$\frac{857(\text{constant})}{60} = 14 \text{ turns, maximum}$$

Spindle Speed. 8000 r.p.m.

Ring Diameter. $2\frac{1}{2}$ inches.

Wind. A combination wind as before.

Procedure

The lay gear to lay gear driver ratio was adjusted to provide 10, 24, and 50 coils per inch, using the gearing combinations previously determined and listed in Table I. Three bobbins, 1 at each coil per inch value, were then spun for a 2 hour period. All were run on the same spindle, and the ring rail was wound to the lowest position at the start of each 2 hour period. A No. 8 Victor traveler was used on the ring during these runs. The bobbin sections were embedded, polished and examined as before, and the packing factors were calculated, tabulated and graphed for comparison with the results of the other tests.

Data

Tables XIV through XVI list the particulars for these packing factor calculations.

In Figure 20, coils per inch are plotted against the calculated packing factors.

Figures 21, 22, and 23 are photomicrographs of the cross sections at 10, 24, and 50 coils per inch, respectively.

Observations

Packing factor was once again seen to rise as coils per inch were increased, confirming the trend and, to some extent, the magnitudes previously obtained for 20/1 yarn.

Textile literature has long claimed that a lay greater than about 35% of the maximum possible would result in a ridged bobbin which could later cause considerable difficulty during unwinding.(1) These ridges did not appear in this particular case even though the 50 coil per inch lay represented 67.5% of the maximum possible. There were no outwardly visible differences among any of these three bobbins of yarn. Further consideration is given this in the chapter dealing with discussion and interpretation of the results of the overall work.

TABLE XIV

10 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.802	.615	.766
2	.799	.606	.760
3	.796	.588	.738
4	.793	.603	.760
5	.790	.582	.737
		AVERAGE	.75

TABLE XV

24 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.784	.642	.820
2	.787	.596	.757
3	.794	.620	.781
4	.771	.633	.819
5	.804	.609	.756
		AVERAGE	.79

TABLE XVI

50 COILS PER INCH

Camera Lucida Drawing	Weight of Paper in Grams	Weight of Sections in Grams	Packing Factor
1	.771	.641	.831
2	.786	.669	.850
3	.803	.679	.846
4	.780	.629	.807
5	.765	.598	.780
		AVERAGE	.82

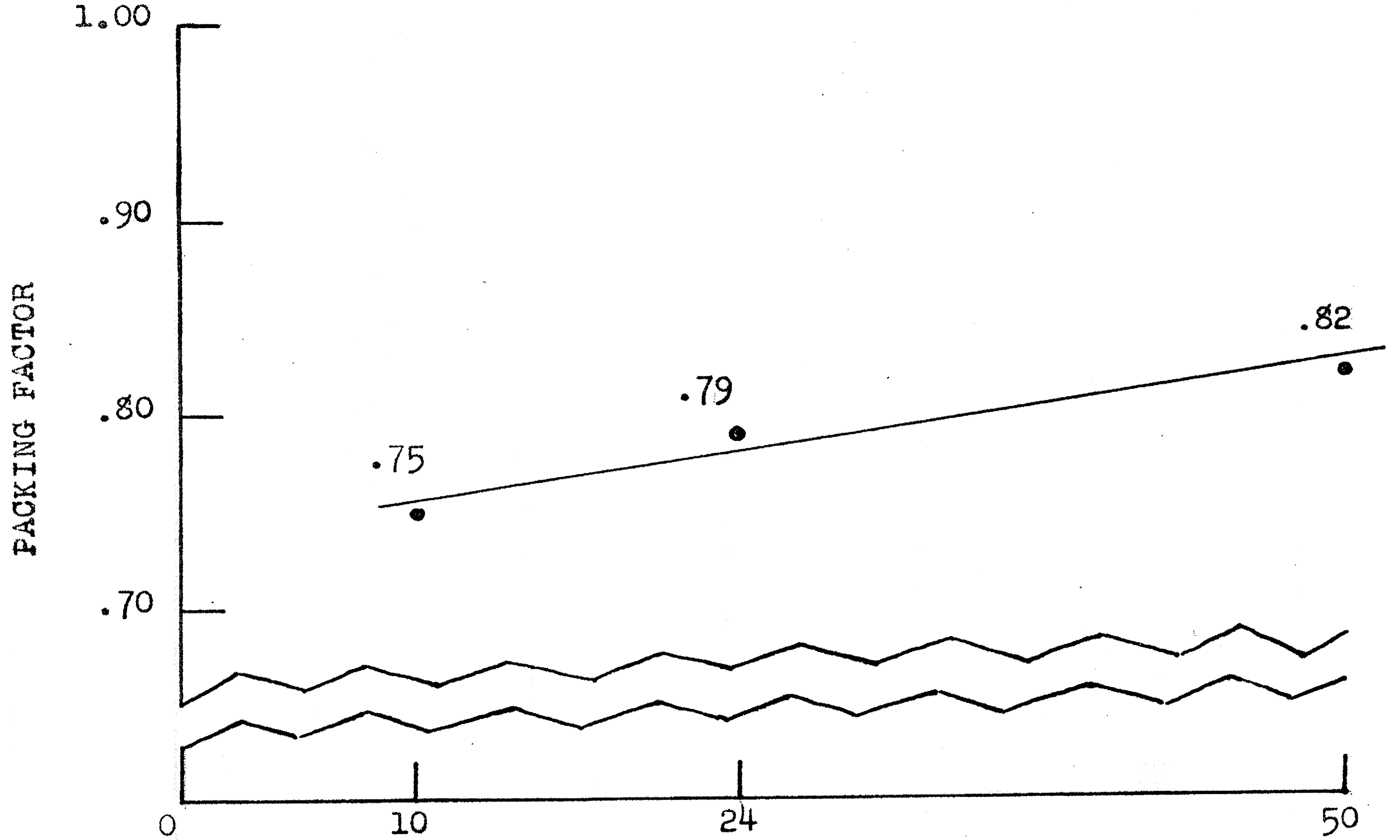

FIGURE 20

VARIATION OF PACKING FACTOR WITH COILS PER INCH

FOR 8/1 YARN

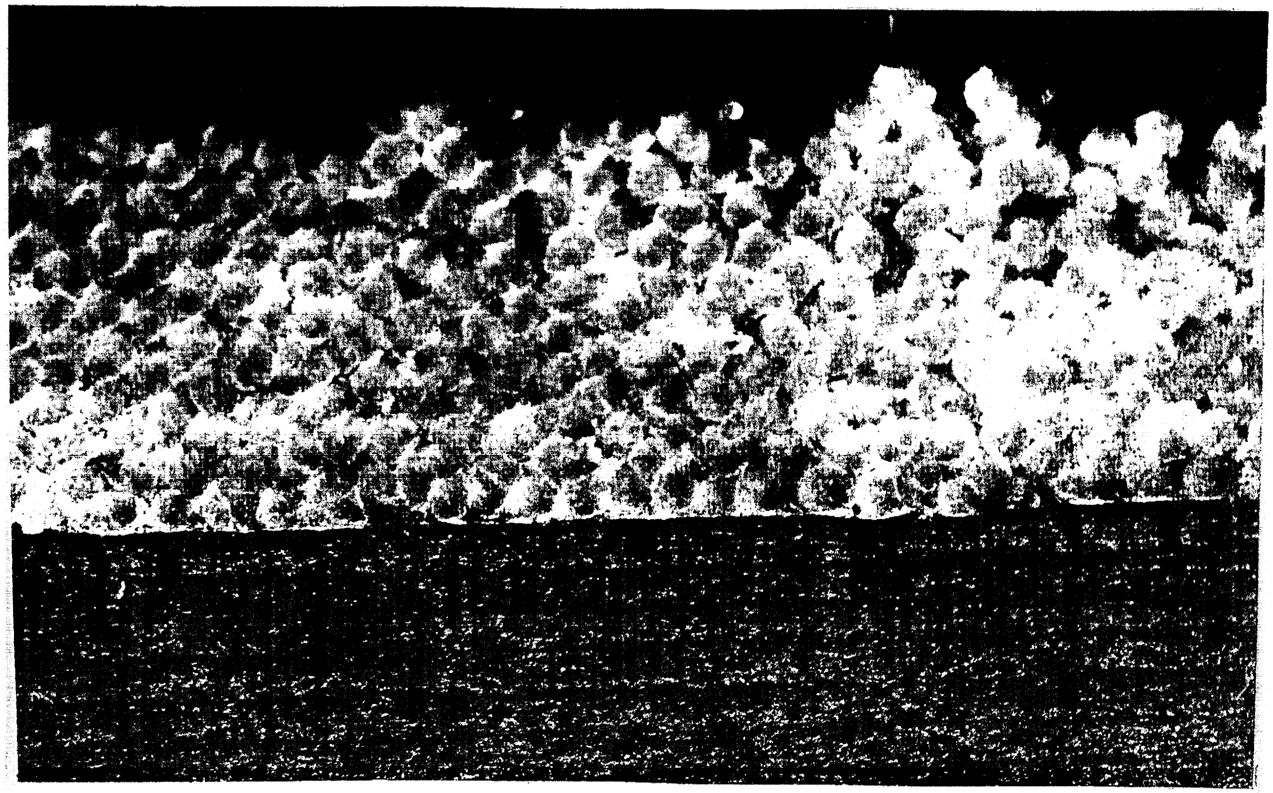

FIGURE 21

BOBBIN CROSS SECTION FOR 8/1 YARN AT 10 COILS PER INCH

MAGNIFICATION APPROXIMATELY 17 DIAMETERS

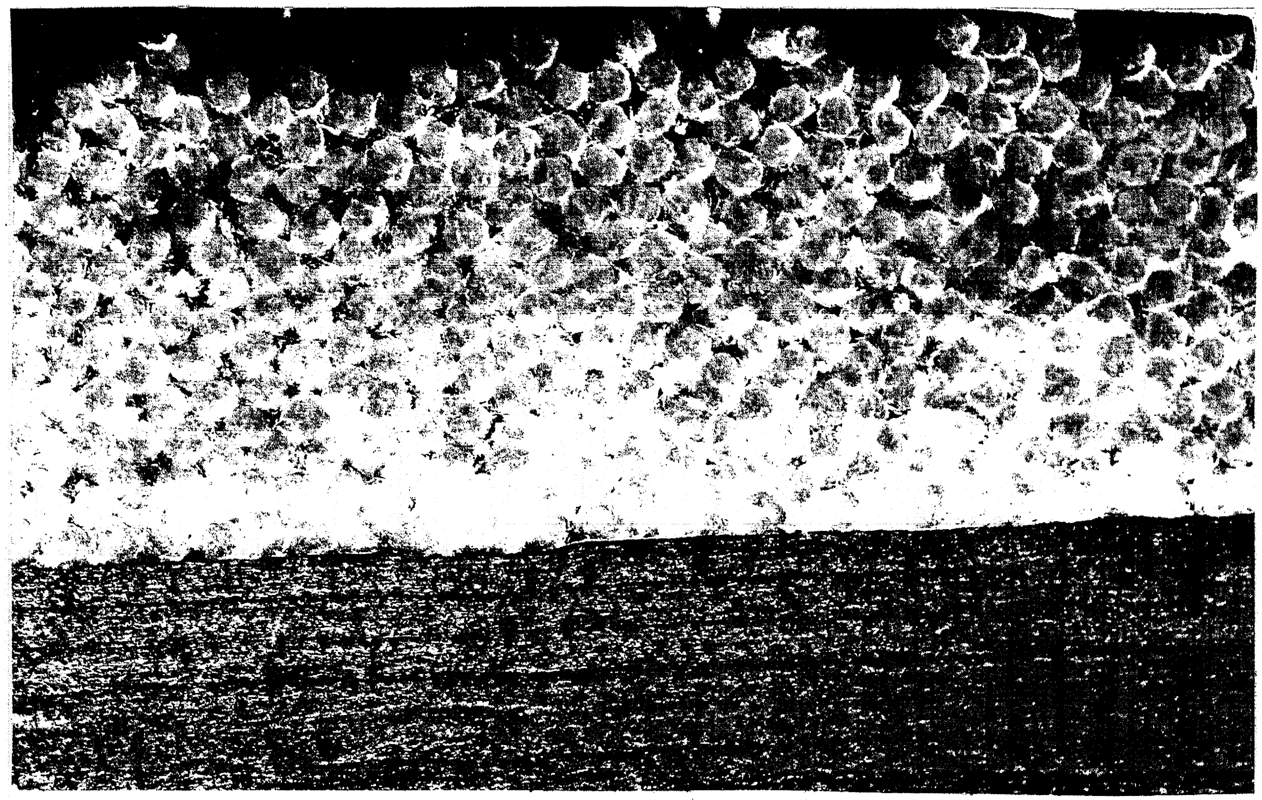

FIGURE 22

BOBBIN CROSS SECTION FOR 8/1 YARN AT 24 COILS PER INCH

MAGNIFICATION APPROXIMATELY 17 DIAMETERS

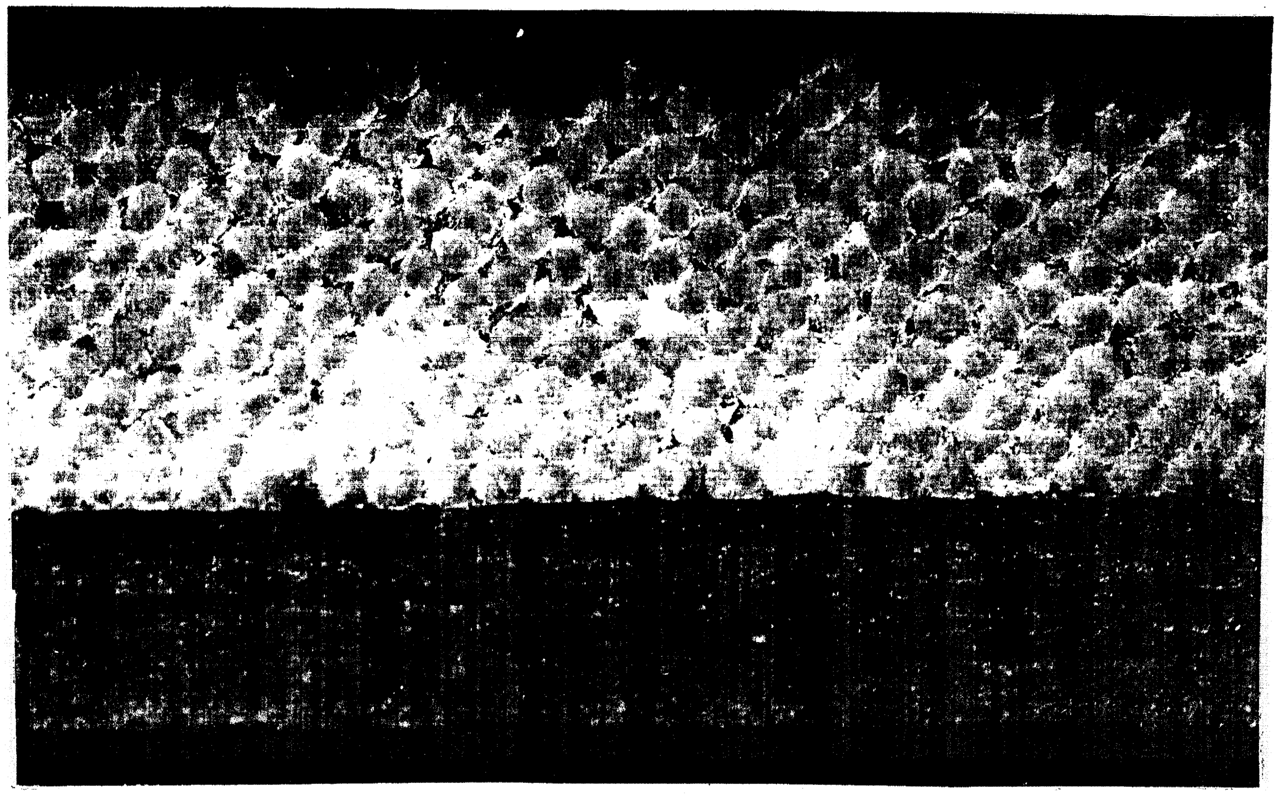

FIGURE 23

BOBBIN CROSS SECTION FOR 8/1 YARN AT 50 COILS PER INCH

MAGNIFICATION APPROXIMATELY 17 DIAMETERS

CHAPTER VIII

DISCUSSION AND INTERPRETATION OF FINDINGS

The Bobbin in Cross Section

Prior to the discussion of the results obtained, a comment concerning the relative merits of photomicrographs and camera lucida drawings for packing factor determinations is in order.

When the first packing factor computations were being attempted early in this work, it was not known whether the camera lucida or the camera would provide better pictures to work with. As the experimentation progressed, however, comparison proved that the camera lucida was superior for obtaining these values. It provided a larger and clearer field of view as long as care was taken in polishing the surfaces of the embedded specimens. Contrast between yarn cross sections and the background was remarkably good, permitting an accurate drawing of the cross section circumferences. It was not possible to obtain this definition with photomicrographs.

Increasing the Number of Coils per Inch

The two series of experiments in which the coils were increased showed, without a doubt, that this practice acted to noticeably increase the density of packing within a given package volume. This suggests that it is a method worth considering if it is believed that an increase in bobbin yardage in a particular case warrants the time and trouble spent on frame adjustments and experimentation while this desired result is sought. This enables the existing bobbins and rings to be used rather than attempting increases in size of these factors.

When working with the 20/1 yarn, it was found that a packing factor of .73 existed for the bobbins wound with 10 coils per inch, and that this figure rose to .79 for the 50 coil per inch packages. For the 8/1 yarn, these values were found to be .75 and .82, respectively. All measurements for computing these figures were taken along the bobbin barrel at the same height, and an area of constant size was always considered when drawing the cross sections under the microscope. Consideration of these corresponding areas within different bobbins insured that the basis of comparison between and among different sections remained valid. This was essential, for visual observation showed that packing became progressively less dense radially, and selection of an area much nearer the outer layers would have radically reduced the packing factor. From the insight obtained during this investigation, it is further believed that packing varies axially also, although not to as large a degree as it does radially. This belief was the basis for taking the sections at the same height on all bobbins. With these careful considerations in mind, it is therefore believed at this time that these packing factor values can be accepted with confidence as valid measures of packing and trend.

It is believed that expression of density of packing in terms of packing factor based on 1.00, as was done here, is a logical and a convenient way to speak of this packing. Percentage increase or decrease is clearly given as experimentation progresses, indicating whether or not the yardage variation within the area examined is significant.

It is yardage gained which is in turn easily expressed in terms of machine running time, which is the desired result in these experiments, indicating concretely whether or not a real advantage can be obtained by this procedure. Although full bobbins were not examined during these tests, it is believed that a fair approximation of yardage gained can be obtained. This shows the significance of an increase in packing of 8% as was obtained for the 20/1, a yardage gain which might not be readily apparent. For this illustration it is believed that though the packing factor varies radially from inner to outer layers, this variation occurs in both bobbins which are being compared. The values of .73 and .79 for these two bobbins, since they are taken from corresponding points near each bobbin barrel, can be safely used in calculating yardage change between the two conditions. Then, assuming that full bobbins are made, the bobbin particulars are:

1. Length of bobbin covered with yarn = 11 inches.
2. Length of traverse = 9 inches.
3. Bobbin outer diameter when full = $2\frac{1}{2}$ inches.
4. Bobbin inner diameter = 1-3/16 inches, average.
5. Yarn diameter of 20/1 $\frac{1}{.9\sqrt{(20 \times 840)}}$ = .009 inches.
6. Taper lengths = 2 inches on both ends.

The volume held is the volume of a cylinder with a height of 9 inches, an outer radius of 1.25 inches, and an inner radius of .594 inches. Volume in cubic inches is:

$$\pi(1.25^2 - .594^2) = 34.25$$

If the packing is considered to be 1.00, or perfect, this means the length in yards contained on this bobbin is:

$$\frac{(34.25)(4)}{(\pi)(.009^2)(36)} = 14{,}900 \text{ yards}$$

If, however, the bobbin had an initial packing factor of .73 and then this was raised to .79 by increasing the coils per inch, the following yardage would be gained:

$$(.79)(14{,}900)-(.73)(14{,}900) = 890 \text{ yards}$$

When viewed in the light that a frame may hold over 200 bobbins, an increase of about 890 yards becomes very significant.

This is, of course, an approximation, but it is believed to express an increase of the correct magnitude. Such an interpretation as this is considered justified in this part of the thesis, a part calling for discussion and interpretation of results, observations and opinions based on the evidence gathered.

Varying Tension by Traveler Changes

From the investigation of the effect of increased traveler weight upon packing, it was found that a change in packing factor of from .75 to .84 resulted. This can be considered as significant an increase as was obtained from increasing the coils per inch. Varying traveler weight, however, is a dangerous procedure. Tension is already a critical consideration, varying in the yarn for different ring rail positions and for different stages of bobbin diameter. The practice of spinning with very heavy travelers cannot therefore be recommended as a method for contributing to optimum wind. The number of "ends down" and resulting poor yarn could very easily nullify the advantages of increaseed yardage.

Popular Mill Practices Examined

The textile mills have a large number of practices and methods of long standing which govern the actions of those who regulate the products and machines during manufacturing. These old rules-of-thumb were long ago incorporated into the literature which describes how to obtain satisfactory results during yarn and cloth manufacturing. A number pertain to methods which a machine operator or someone of higher authority can use to make adjustments during change-overs, then indicating how he can, by eye and hand, judge the results. These people usually are not aware of why a certain action is taken and why it brings the desired result. They only know that it usually does, and this is reason enough to use it.

Two important statements of long standing were encountered again and again in the literature during the course of this investigation. These statements, in various wordings, referred to areas with which this experimentation was directly concerned, and so these statements and the experimental observations made concerning them follow.

Statement. "While it would seem that cotton yarns could be wound close enough so adjacent coils would just touch each other and form a complete and uniform layer on the bobbin, it cannot be done on the spinning frame. Because of the varying poistions of the traveler on the ring and the distance the traveler is from the bobbin, yarns tend to wind in ridges when the ring traverses slowly enough to lay coils side by side. Commercial practice has settled on a lay that ranges from 28 to 35 per cent of the maximum with many bobbins wound with about 33 per cent of the maximum lay."(1)

Comment. When running the bobbins of 20/1 cotton at 50 coils per inch on the upward traverse, this range of 28 to 35 per cent was somewhat exceeded, 50 coils ÷ 117 being equal to approximately 43 per cent. No rigid appearance was formed during any of these runs. For the 8/1 cotton yarn, 50 coils represented 50 ÷ 74 = 67.6 per cent of the maximum number of coils. With the recommended percentage so greatly exceeded, ridges should definitely have been formed and should have been extremely obvious. However, there was no outward difference in surface appearance between these bobbins wound with 50 coils per inch and those wound with 10. The close lay of 50 evidently still had sufficient control to position the coils without over-riding.

It is believed that there no doubt is a point beyond which it is not practical to increase the coils per inch. Vibration of the ring rail would have to be eliminated and the builder cam would have to be ideal in cut and smoothness in order to place each coil perfectly against the preceding coil in the building process. It was, however, probably a marked increase in the efficiency of these frame parts on the laboratory model which permitted the coils per inch to be raised considerably above the predicted percentage. The point where ridges would noticeably begin was not reached, indicating that for the frame used, the point was higher than 67.6 per cent of the maximum lay.

Statement. "A few teeth of difference in the size of the lay gear used if often the difference between good and poor packages, and between normal wear and excessive wear on equipment."(3)

Comment. The lay gear seems to be a change wheel which, once set, receives little attention in the mill. With the same yarn counts usually run on the frames year after year, few pronounced changes are required.

Should the mill decide to radically alter the number of coils per inch, however, it would find, contrary to this Victor Ring Traveler statement, that a few lay gear teeth are not at all critical. This fact was discovered early in this thesis work during the initial attempts to vary coils per inch from a very low number to the maximum possible. The spinning frame was, upon arrival from the Whitin Machine Works, set with a 50 tooth bevel gear driving a 45 tooth lay gear. Experimentation showed that this combination placed 24 coils per inch on the bobbin. A change of 15 teeth in the lay gear, considerably more than the "few teeth of difference" mentioned, dropped the coils per inch to only 18. Further experimentation showed that with the 30 tooth bevel gear driving the original 45 tooth lay gear, 13 coils per inch were obtained, and substitution again of the 60 tooth lay gear dropped the coils only to 10 per inch. The only way in which the range of 10 to 50 coils per inch was finally established was by varying the ratio between the bevel gear and the lay gear by using a range of from 30 to 60 teeth on the lay gear in various combinations with the 30, 50, and 78 teeth bevel gears available.

Summary

This investigation has concerned itself with examing the problem of an optimum wind for textile yarns. That there is a problem, a real one, is indicated by the interest in, and trend toward, large package spinning. That the problem is unsolved is further indicated by the lack of information in any literature except for the repetition of certain experimental, mechanical manipulations recommended for trial-and-error. That the problem as applied to the winding of all yarns in all existing forms has been but lightly touched by these long hours of thought and labor is all too painfully evident. That a good beginning has been made, however, can be claimed, for certain aspects of this winding operation have been isolated and viewed carefully. Although restriction to cotton yarn and the bobbin had to be effected in order to narrow the confines of the problem initially, the results can be expanded to other yarns and forms. The discussion of these results obtained illustrate that a reasonable beginning has been made and that future thought and experimentation is worthwhile.

CHAPTER IX

SUGGESTIONS FOR FUTURE INVESTIGATION

Effect of Taper on the Combination Wind

The factors which determine the physical dimensions and composition of a bobbin of yarn were earlier listed as coils per inch, yarn tension, and the length of the taper. These first two factors were dealt with at length, and the effects of variations within each were isolated and measured. An examination of optimum package as defined in this work, however, makes mandatory a consideration of taper and its importance to the package during formation, handling and processing. An examination of taper therefore is the next logical and necessary step in this study.

Certain ideas concerning taper have arisen and have been considered during the course of this investigation. Although these views are primarily initial thoughts, they may provide a substantial basis for future investigations. These impressions are therefore discussed in the light of this past work on winding.

Taper has almost always been considered an individual mill problem, one to settle experimentally in view of the handling, spooling and winding the various packages will receive. Each mill, after many years of operation, has arrived at the best taper it can experimentally attain. Probably no one knows if, for this particular mill with its particular packages, this taper is the optimum, but it serves the end purposes better than the other tapers considered.

Importance.

Taper is an important consideration because:

1. It dictates whether yarn will slough-off during doffing and handling.
2. It determines whether unwinding will also cause slough-offs.
3. As a minor consideration, it affects the yardage on a bobbin.

The first instance where a given taper will be tested is during doffing. The doffer, grasping the bobbin and pulling upward, has his hand in contact with the outer layers. This can cause these outermost traverses to slide longitudinally, rolling off, or in textile terms, sloughing-off, the rounded shoulders of the package if this motion is pronounced. If the taper is too short, even a slight longitudinal motion may be enough to cause the coils to move over the shoulders, thereby ruining the package. This can, of course, also occur if the motion downward is sufficient to move the coils below the lower shoulders of the package.

Taper exerts further influence during unwinding of the yarn if the unwinding is done "over the nose" of the bobbin. Once again some longitudinal movement of the coils may occur due to the friction of yarn dragging across the outer layers at high speed. As before, this movement may be sufficient to cause these layers to slough-off the tapered edges.

Factors Influencing Yarn Sloughing.

For any given taper, yarn slough-offs are probably influenced mainly by the following:

Yarn Count. A small longitudinal movement equivalent to a few fine yarn diameters can start the sloughing of the coils off the shoulders of a bobbin of very fine yarn. Taper therefore may be more of a problem at the fine yarn counts.

Yarn Tension. The tighter the coils around the bobbin circumference, the greater the resistance to sloughing during handling. During unwinding over the nose of the package, however, the relaxation of the yarn may increase the possibility of binding due to intermingling of coils.

Coils per Inch. The coils per inch determine how the outer traverses are placed with respect to the preceding layers and the adjacent coils. A wide spacing between coils in the traverses may permit some yarns of the outer layer to seat between the coils of the preceding traverse or even earlier traverses. This intermingling could prevent sloughing during handling, all yarns of the last traverse not being in contact with the doffer's hand. During unwinding, however, these coils may well bind with those of the other traverses, pulling a substantial number off the shoulders of the tapers.

Yarn Extensibility. The greater the extensibility, the greater the chance, it seems, that yarns could be stretched enough to cause sloughing-off during handling. This probably is a factor which adds to the difficulties experienced in winding a fine yarn. The finer counts will have less resistance to stretching, and will at the same time require less longitudinal movement to slide off over the tapers. High extensibility therefore could reinforce another dangerous factor, increasing the dangers of sloughing, while low extensibility could counteract this tendency.

Yarn Friction. High friction between yarns may be an aid during handling, but could quite well be a hindrance during unwinding, causing a number of coils to be pulled off the bobbin at once as yarns bind together. Yarn surface characteristics therefore assume considerable importance in this problem.

Suggested Experimentation

The initial investigation that these views suggest is one where a given taper is selected and these controlling factors are varied to observe the effects on sloughing-off. The examination of the influence of coils per inch with various yarn counts and yarn tensions during unwinding and handling should contribute to the knowledge of what exactly is happening at the critical taper edges. A slow motion picture study of how the unwinding occurs at the tapers for various conditions appears to be a desirable feature of this investigation.

A second investigation which suggests itself is variation of the taper length using a high number of coils per inch followed by variations using a very low number of coils. From investigation of how great a taper range can be established at each condition before the change is reflected in handling and unwinding, an idea of how critical taper is can be established.

For both of these studies, embedding the bobbins in plastic, sectioning at the tapers, and examining the sections under the microscope should provide an excellent method of observing the effects of the variations attempted.

Summary

This investigation of taper, and therefore sloughing-off, will enable more to be determined about a major mill consideration. However, the problem still seems to be peculiarly individual, being settled in view of particular package size, yarn count, handling during doffing, and unwinding. Once a certain concern has experimentally determined a taper which functions effectively, variation and experimentation, unless there is a slough-off problem, serve little useful purpose. Some small yardage gain may be obtained, but this seems hardly worth the effort. The taper, in this case, can therefore be thought of as optimum for all practical purposes. If a decided sloughing-off problem does exist, though, it may well be worth considering coil per inch and taper length variation in various combinations to observe if this shows any promise. The best answer, however, may be converting to a filling or a warp wind or some modification where the complete package structure is changed.

Other Yarns and Packages

Consideration during this investigation was given to cotton yarn wound on bobbins. Subsequent investigation can move on to cotton yarn wound on the remaining packages, such as cones and cheeses, where an optimum wind may be desirable. This, in turn, can lead to work with other fibers, other packages, and other winding machines, gradually covering the areas of the winding problem as existing in the mills at the present time.

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