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TEXTILE FIBERS AND THEIR USE

4TH EDITION



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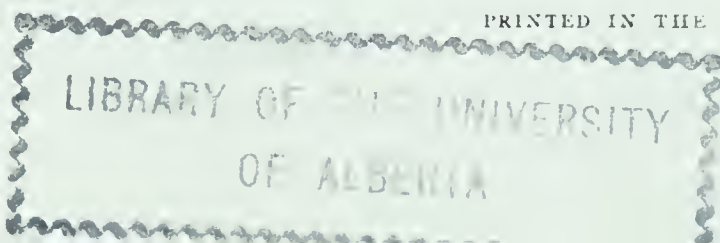
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Preface

As in the case of the earlier editions, this fourth edition represents a thorough revision and a further expansion of subject matter in response to new developments in the field of textiles. Again, changes in synthetic fibers and finishes of fabrics have taken place with amazing rapidity, necessitating marked revision to bring the subject matter up to date. In keeping with modern trends, greater emphasis has been given to consumer interest in textiles. A reorganization of subject matter has been made to stress this interest.

Throughout the text is emphasized the importance of a knowledge of certain fundamental facts concerning textile fibers and the fabrics made from them. With the increasing complication of manufacturing processes and the evolution of our complex system of distribution, the distance between the producer and the consumer has been greatly lengthened. As a result, the casual acquiring, through personal observation, of those facts which are basic for intelligent selection and use has become improbable. Today, definite organized information covering the field is recognized as essential for wise consumption. *Textile Fibers and Their Use, Revised*, attempts such presentation of subject matter on a level suited to college instruction.

It is hoped that through the presentation of this material the following needs of the student will be met, at least in part.

To appreciate the importance of textiles in the economic and cultural life of man.

To know the characteristics of commonly used textile fibers and fabrics.

To know how methods of construction, fibers, yarns, and finishes influence and alter cloth.

To become familiar with special finishes, their possibilities and limitations.

To know how to select suitable and durable clothing and household fabrics.

To know how to care for textiles.

To understand some of the factors which affect the cost of clothing and textiles.

To understand the purpose and effects of government regulations as they concern labeling, advertising, adulterations, and taxation of textiles.

To learn to use scientific methods in the solution of problems pertaining to textiles.

In a text treating with so wide a field, it is necessary to draw from numerous and varied sources. In such cases the indebtedness of the author to others is unlimited. Numerous references throughout the book acknowledge in part this assistance.

Acknowledgement is made as follows:

To her Dean, Dr. Margaret Justin, without whose aid the text might not have been written.

To her colleagues at Kansas State College who have given encouragement and assistance in many ways.

To authors and publishers, including those of technical journals, who generously permitted use of illustrations and subject matter.

To the many manufacturers and others for the use of illustrations.

KATHARINE PADDOCK HESS

Suggestions to the Teacher

In treating a field of so wide a scope as that of textiles, it is necessary to select only those topics that are of vital importance to a working knowledge of the subject and that will meet the needs and interests of the student. The subject matter presented in this book is designed to acquaint the student with fabrics and the factors influencing their wearing qualities and appearance, and to give the practical application of this knowledge to the everyday problems of the consumer.

The labeling of cloth with test specifications is among the important problems of manufacturer and consumer alike. This subject is given some consideration in the text but may further be expanded and developed in its presentation. It is hoped that the teacher will obtain references to the current periodicals and bulletins and thus direct further study on the subject. This phase of textiles is relatively new, and rapid changes and wide developments are to be expected.

Special attention is directed toward the presentation of the subject of textiles in an interesting and effective manner. The presentation of the subject of fabric construction by means of photographs, films, and slides will simplify and clarify the subject and permit the handling of that portion of the text in a much shorter time, thus allowing greater consideration of the third section on textiles and the consumer. Lantern slides and film strips of assistance to teachers may be obtained from the office of Extension of the Department of Agriculture. The presentation of the subject matter in the form of units to be solved by means of problems permits the teacher to adjust the course by omitting such problems as are not suited to her group. The references for further study provide additional work for the entire class or for those students especially interested.

Throughout the text suggestions are made for supplementing the assignment by additional problems. Inclusion of laboratory work on textiles has been found highly desirable. Provision has been made for laboratory work in the textile laboratory manual prepared for use with this text. The suggestions at the end of each problem are worked out in detail in *Textiles Workbook* by Hess and Cormany.



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Introduction

TEXTILES AND HUMAN PROGRESS

EACH civilization has the amazing habit of regarding itself as the culmination of all that is right and good in a cultural pattern or way of life, and of looking with criticism or indulgence on those slowly evolved and different patterns of other civilizations. It is true that each period is indebted to those that have preceded it, even as it is reflected in its turn in the period that follows it. Not always has only the good been wholly conserved; not always has the trend in achievement been consistently upward nor evenly spaced in time; yet, there is a trend in human progress interesting to us all. Prentice says: ¹

Through the slow experience of the ages, man has learned to accomplish much that at first was impossible and how to accomplish easily what before had been difficult. The growth of civilization, therefore, has one single cause—the increasing efficiency of man's labors. Savagery is the condition in which man lived when much effort brought small results. Progress comes with decreasing effort and increasing results. Civilization begins when man's effort is so productive that he can diversify his labors, spending for new comforts the labor which had previously been devoted to the maintenance of life. In modern terms, civilization has advanced with the constantly decreasing cost of production. Refinements and amenities, comforts, luxuries, books, and all that to the modern world make life worth living are a surplus arising after primary needs have been met and these primary needs are insistent. To civilized man as to the savage, food, clothing, and shelter are

¹ Ezra P. Prentice, *Hunger and History*, p. 1. Harper Bros., New York and London, 1939.

essential. Man must be fed, protected from the elements and from his enemies and the search for refinements must wait until these needs are satisfied. Human progress can, therefore, be measured by the ease with which the necessities of life are provided. Costly food, costly shelter, and costly protection mean comparatively increased effort to provide for essential needs, with consequent decrease in the surplus which makes life worth living.

In our civilization textiles have become "necessaries of life," as they provide in a major way for man's clothing and for many sundries concerned with his shelter. In early days, yarns were spun and fabrics woven by the people who would use these goods or by their neighbors. Today, due to the Industrial Revolution and later developments, few people need to know how to spin or weave. But many people need to know how to judge the quality of machine-made fabrics. The machine age has put too much space between production and consumption to make possible unconscious assimilation of necessary knowledge. We need information concerning each article we buy with regard to the services it will give and the length of time it will completely satisfy our demands on it. Hence, the study of textiles becomes important to all consumers, and fabric construction and fiber identification take on enhanced significance. The purchase and care of textiles is recognized as one of the major problems of the consumer, worthy of serious consideration and earnest efforts toward solution.

The situation today is far from this ideal. In no industry has research progressed sufficiently to enable manufacturers or finishers to produce an article for which they are able to assure or even predict absolute performance. The production of textiles is no nearer perfection than is any other industry. However, much progress has been made recently and is being made continually. Not only is the textile industry one of the oldest industries in the world, if not the oldest, but it is ever closely related to the evolving pattern of civilization. At the present time it is one of the greatest industries in America as evaluated in terms of the number of persons employed,

the amount paid annually for wages, and the amount of capital invested. Statistics reported in 1937 that there were 1,814,387 Americans engaged in the various phases of the textile industry in that year; the annual expenditure for salaries and wages by the textile industry was stated as \$1,549,559,132; and the capital investment was well over \$4,089,124,016. This may be compared with 889,298 Americans employed in food industries at an annual expenditure of \$977,776,070 for wages and salaries and a capital investment of \$7,911,368,187. From this, the importance of the textile industry in the economic life of this country becomes apparent, and the importance of textiles in the life of every individual is evident.

Section One

TEXTILE CONSTRUCTION, PROCESSING,
AND DESIGN



Unit One

HOW FABRICS ARE CONSTRUCTED

THE origin and development of fabric construction is a subject on which authorities do not agree. According to some authors felting was the first method used by man. The fact that the wool of wild animals became matted or felted together probably suggested this process. Other authorities claim that weaving or braiding appeared first, in imitation of the manner in which the leaves of palms were interlaced.

Whether short fibers were constructed directly into cloth or into continuous lengths which were interlaced or inter-looped into fabrics is of secondary importance. Fabric construction may well be considered one of the triumphs of man, ranking in importance with the utilization of fire and the invention of the wheel. The significance of textile construction lies in the fact that such small units as fibers may be built into structures such as felts, yarns, and cloth in such a manner as to maintain the properties of the individual units and accumulate their strength and durability. The manner in which fabrics are constructed determines to a great extent the characteristics of the cloth; hence, a study of the chief methods of construction is of great importance.

Today there are four important methods by which cloth is produced: matting of loose fibers, weaving, knitting, and braiding.

PROBLEM 1. HOW ARE FABRICS MADE FROM LOOSE FIBERS?

Felting. Wool, the fiber covering of the sheep and other animals, is the one natural fiber that possesses a property

which will permit it to be made into a fabric without first making the fibers into a continuous length or yarn. This individual characteristic property of wool is known as the felting property.

Felting is the construction of a fabric from loose wool fibers. According to the definition adopted by The Felt Association, Inc., July, 1944, "Felt is a fibrous material which is built up of interlocked wool fibers by mechanical and chemical action, moisture, and heat. The blend may consist of wool and other fibers." Dr. Hardy described the action of the wool fiber during the process of felting as follows: "Wool fiber when being worked travels in the direction of the root and tends to turn back upon itself, thereby entangling and enmeshing other fibers."

This definition of felt eliminates, as felt, materials other than wool or wool blends. The explanation of the process distinguishes it from all other methods of fabric construction.

Most authorities agree that the felting property of wool is due to the scaly structure of the surface of the fiber and its crimp nature as well as to the ease with which it can be deformed and recover from this deformation. If pressure is applied or the fiber is agitated when in a moist condition, it tends to travel in the direction of the root end. The presence of acids or alkalies increases the ease of movement. Moisture causes softening and swelling of the fibers so that they adhere to each other.

Wool growing on the animal becomes combined with dirt, vegetable matter, and body grease. Before wool is used, this extraneous material must be removed and the fibers separated and softened.

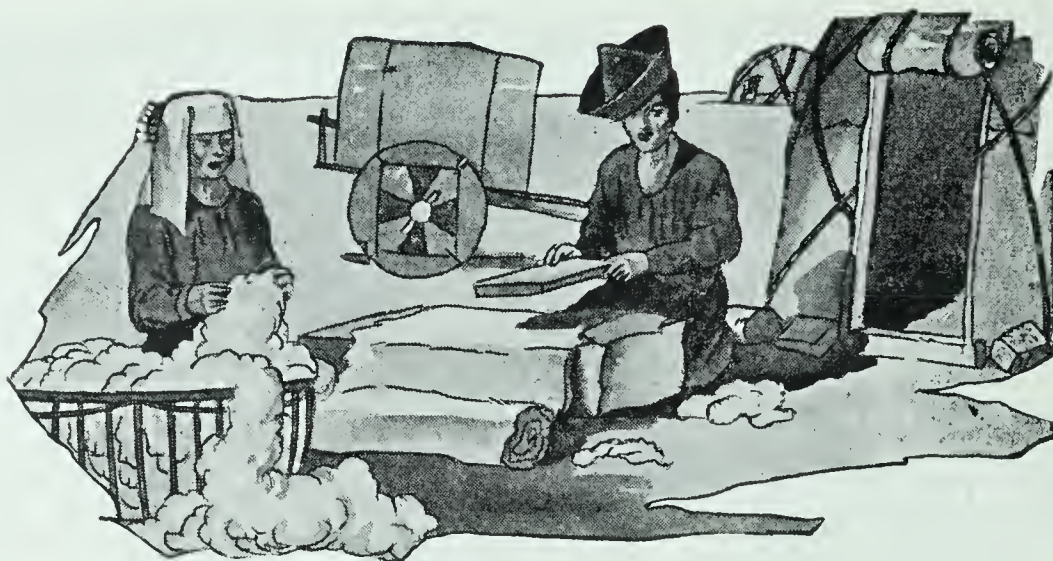
Primitive method. Certain tribes in Tibet today use the primitive process of manufacture just as their ancestors did thousands of years ago. The principal instrument used is a large mat on which layers of wool are spread until the desired thickness is secured. Water, with grease or oil, serves as the fulling agent. The mat is rolled up under firm pressure with the foot and is then unrolled and rerolled from the opposite end.



Courtesy Robert Keith Furniture and Carpet Co.

Hand-embroidered Numdah rug, showing decoration of felted fabrics.

This process of rolling back and forth is continued for a period of four or five hours, during which time the fibers become firmly and closely matted together. The felt is then taken up, washed, stretched on the mat, and dried in the sun.



Courtesy Western Felt Works

Mongol women making felt in primitive times.

Modern method. The general principles involved remain the same; and selected materials, specially designed machinery, a research laboratory, and an engineering staff are regarded as essential to felt production in America today. Under these conditions the modern process of making felt is as follows: ¹

Wool used for felting consists principally of fleece wool in the grease. This wool is packed in bags weighing from 250 to 375 pounds and containing from 30 to 50 tightly rolled fleeces. (See page 72.) To this may be added wastes from woolen mills and clippings from tailor shops. The first process is the sorting and inspecting, in which the wool is graded according to fineness, color, and length. It is then cleaned by scouring, which removes most of the foreign matter. If the wool contains burrs and vegetable materials that are not removed by scouring, it is necessary to dampen it with a weak solution of sulfuric acid and then subject it to heat. This process reduces the vegetable matter to carbon, which is crushed by heavy rollers and removed by dusting machines.

The cleaned fibers of different qualities are mixed or blended to obtain the particular quality desired. The "mixed" stock is then carded to complete the cleaning and to

¹ Berthold Laufer, *The Early History of Felt*, pp. 23-25. Western Felt Works, Chicago, 1930.



Courtesy Texas A. and M. College Extension Service

Herd of sheep in pasture. Note the ridges left by shearing shears.

thoroughly untangle and straighten the fibers. The carding machine consists of two cylinders covered with card "clothing," which is leather or fabric studded with many fine wire teeth. The carded wool is delivered in a thin sheet 80 to 90 feet wide. This thin web of fibers is deposited onto a circulating belt on which it builds up into a soft fluffy "batt" from $\frac{1}{2}$ to 2 inches thick. Two carding machines are set at right angles so as to deliver to the same belt. Thus there is built up a batt in thin layers of fibers that are lying at right angles to each other. After being trimmed to uniform size, the batts are first rolled, then moistened with water and placed between two heavy plates, the top one of which is vibrated. This causes the moistened fibers to be interlaced and entangled. From two to twelve batts may be pressed together, the number depending upon the type of finished article desired. The machinery is automatically controlled so



Mechanical shearing of sheep.

that it stops when the desired thickness and hardness of the felt are reached.

Fulling, the next process, consists of shrinking the felt by rotating it slowly in bowls where wooden hammers compress and release the material. Either soap or sulfuric acid is necessary to produce and control the shrinkage. The felt is then neutralized, scoured, rinsed, and dried. Drying is done by passing it through wringers; then it is placed in centrifugal extractors and finally stretched to the desired width in frames where the temperature is raised to 150 degrees or to 275 degrees, depending upon the type of felt.

Soft and medium felts are given a broadcloth finish by shearing; firm felts are sanded. Cylinder presses are used in the pressing of thin felt, but heavy steam-heated plates weighing many tons are necessary for the pressing of thick, firm felt.

After the pressing, the felt is folded or rolled and placed in a boxlike machine with curved ends and with hammers



Courtesy Kenwood Wool Products Co.

Drawing of wool fiber, showing the overlapping of the scales.

hanging from a shaft. These hammers swing back and forth, pushing, pounding, and rolling the felt until it acquires proper thickness, firmness, length, and width.

The felt now passes through a washing machine, equipped with heavy rollers, and is thoroughly cleansed. If the felt is to be finished in a gray or natural color, it goes to the dryer; or if in colors it goes to the dye house and then to the dryer. The finer qualities of felt are passed through a shearing machine, where all loose ends of fibers are cropped from the surface, and then through a steam-heated heavy rotary pressing machine, which gives a smooth lustrous finish, as well as proper thickness.

Felt is classified as *wool* felt, that made from the fibers of sheep, and *fur* felt, made from the fur or short fibers of rabbit, beaver, or other animals. In the construction of fur felt, the long outer layer of hairs, which is never used in the felt, is removed by a clipping machine. The pelts are then treated with nitrate of mercury and stored for a few weeks to soften them. The skin is shredded or shaved from the fur by a whir of sharp spiral blades from which it emerges still in the form of the pelt. The next step is the removal of the remaining bits of hair and dirt. This is done by passing it through a blower.

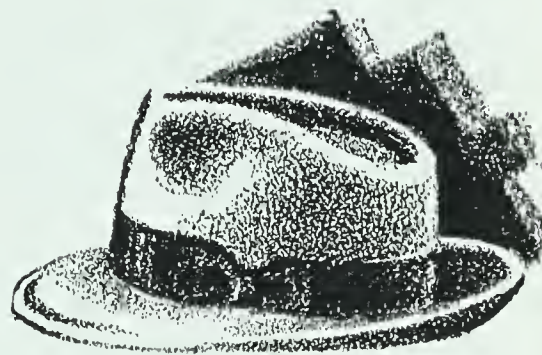
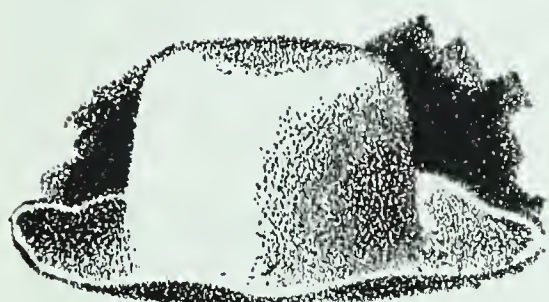
The blending of various grades of fur is an important step in the determination of quality. For the best quality of hats, beaver fur is used; and muskrat may be added to give it a sheen. For medium- and lower-priced fur felts, rabbit is used.

In the construction of hat felts from fur, the cleaned and blended fur fibers are carried by a blast of air onto the required shape, where they are held in position by suction until the desired thickness is obtained. Stiffening agents are used as required as the felt is developed. It is possible to use one type of fur for the body of the felt, and the fibers blown on for the top layer may be of a different type of fur. (See page 11.)

Felting is a comparatively inexpensive method of fabric construction in which short fibers can be used. The fabric is inelastic and comparatively thick and lacks strength. These characteristics necessarily limit the use of felt as a clothing fabric but especially adapt it for use wherever silence, padding, or warmth is required.

In comparison with the limited uses made of felt by the ancient people, there are today many and varied uses for felt. It is used for hats, shoes, and other articles of clothing. However, its wider field is in the industries for articles such as piano hammers, filters, automobile parts, weather stripping, gaskets, wicks, and numerous other articles.

Recently, special styling of house shoes and jackets and the production of novel fabrics of unusual construction have increased the field for felt goods.



Courtesy Textiles Education Bureau

Steps in the production of fur felt hats.

The felting property of wool is made use of not only as a method of fabric construction but also as a finish for wool goods. This principle is also employed in the construction of wool garments when fullness is removed from the top of sleeves by steaming and pressing and when collars are steamed and shaped, and in the pressing of wool garments when the fullness or bagginess is removed from skirts and trousers by steaming and pressing.

Suggestion for the Laboratory ¹

How may the knowledge of the properties of wool affect its handling in the home?

Subject clean wool fibers to heat, pressure, and moisture until

¹ Full directions for the exercises and experiments as well as space for writing up the work and mounting specimens are provided in the accompanying laboratory manual, *Textiles Workbook* (J. B. Lippincott Co., Chicago).

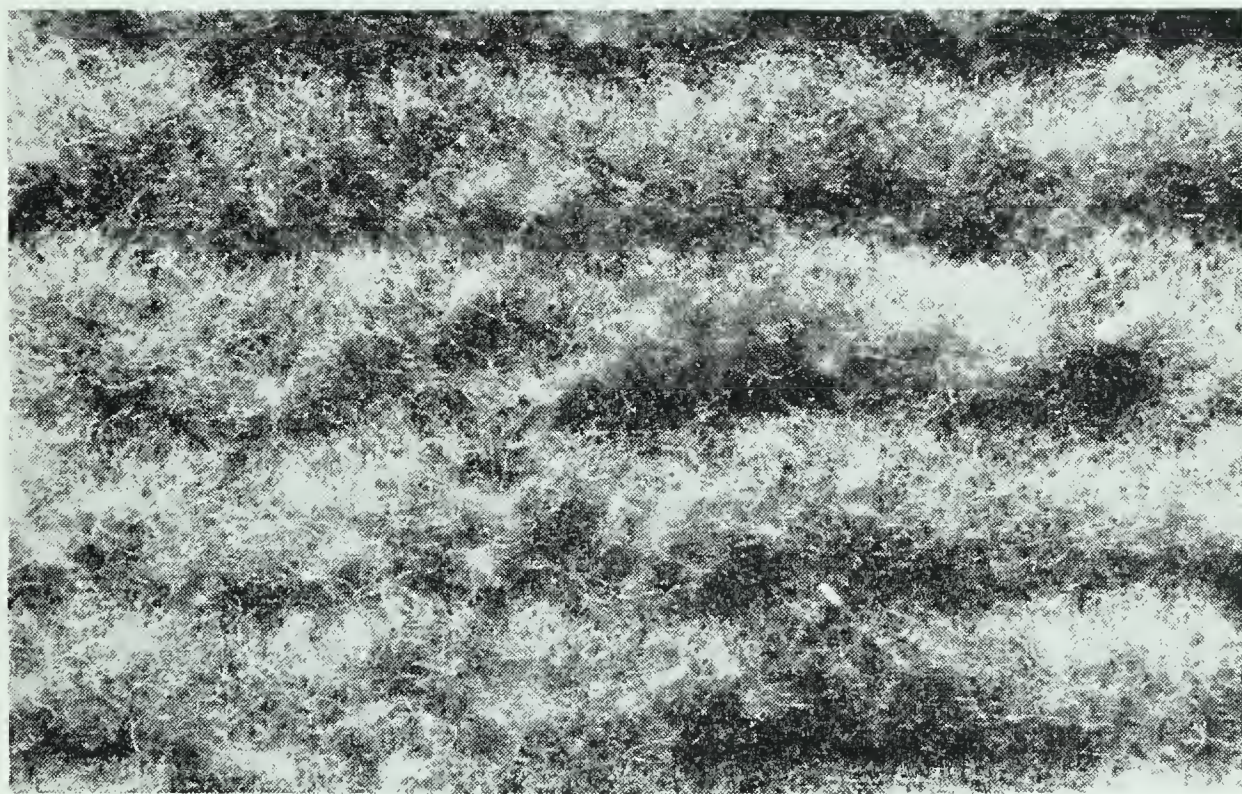
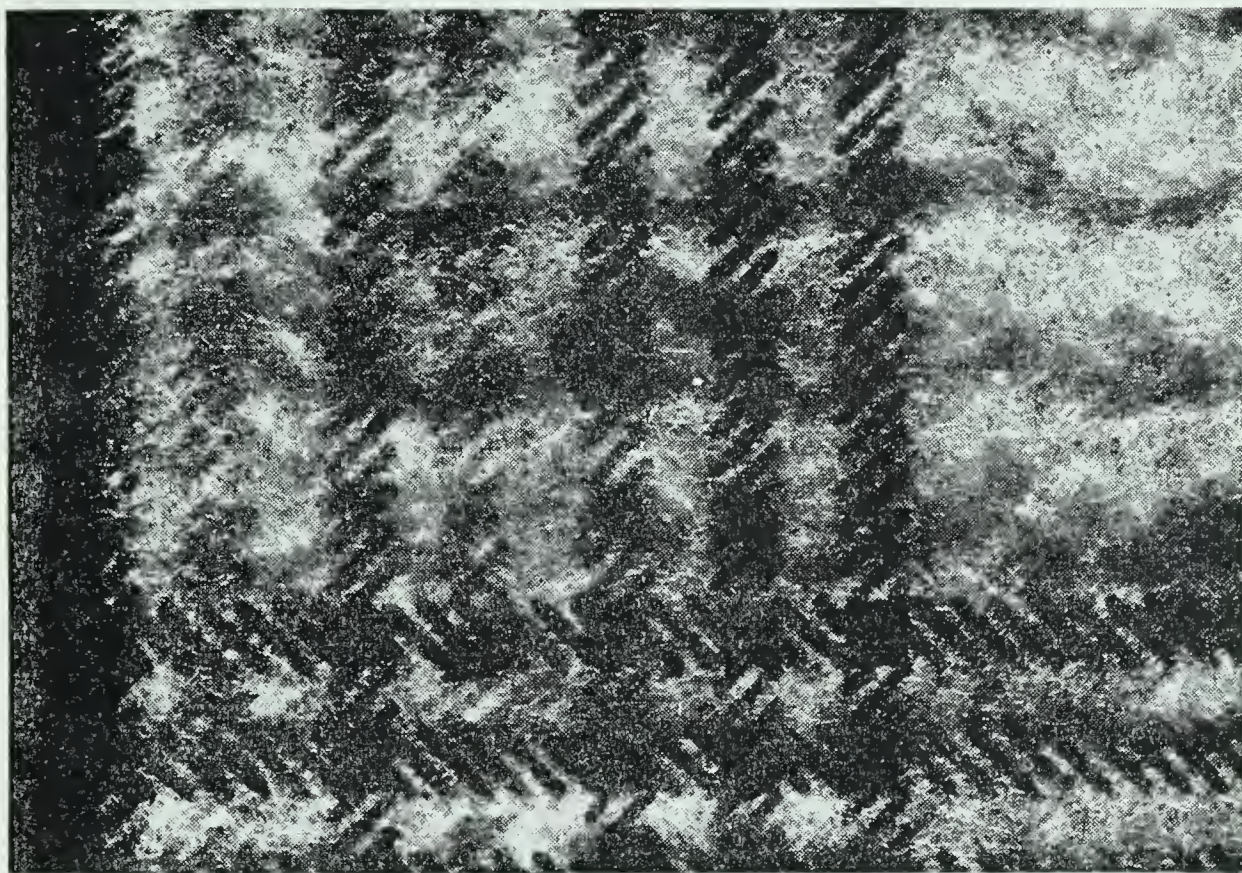
a compact mass is formed. Note the ease with which the wool scorches even when protected with cotton.

Bonded fabrics. Although the cotton fiber does not naturally possess a property that will permit its being constructed into a fabric without first being made into a continuous length or yarn, this property may be supplied in the form of a binder. The making of loose cotton fibers directly into cloth without spinning or weaving is a recent and revolutionary step in the textile industry. In this new process cotton is handled in a manner similar to the processing of wool for the production of felt. Cleaned cotton fibers are laid lengthwise into a sheet about one-fourth inch thick. This sheet is first compressed by running it between rollers, and then a plastic of synthetic resins or starch is printed onto it in wavy, crosswise lines about one-quarter of an inch apart to serve as the binder. After printing with the plastic, the material is dried. Design may be applied in the same operation by adding color to the plastic binder, or a design may be printed onto the fabric. (See the illustration on page 13.)

This new nonspun, nonwoven fabric is inexpensive, as many processes are eliminated and less fiber is required per yard of fabric. It is claimed that one pound of cotton will make three times as many yards of bonded fabric as of woven material. At present, cotton is the principal fiber being used in bonded fabrics; however, experiments are being made with various other materials, including synthetic fibers. The choice of synthetic resins and starches depends upon the use of the final product. Bonded fabrics are soft, highly absorbent, and do not disintegrate when wet. They do, however, lack tensile strength and should not be used where high tensile strength is required. Commercially available articles of bonded cotton include luncheon sets, hand towels, and other small articles intended for limited use.

PROBLEM 2. HOW ARE FABRICS WOVEN?

The origin and development of the construction of fabrics from strips or strands of material is a subject on which au-



Bonded cotton cloth with and without printed design.



Courtesy Floyd and Marguerite Schultz

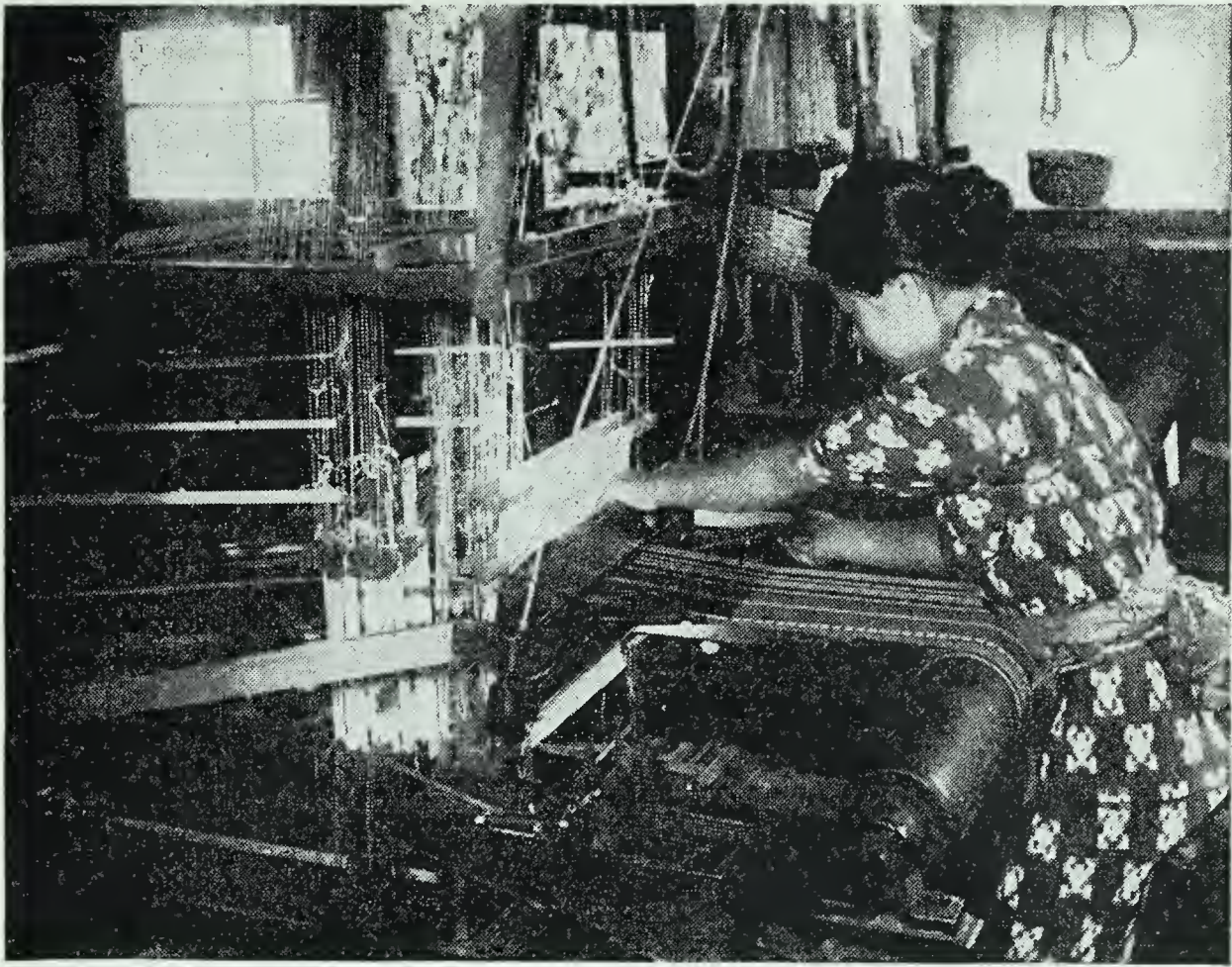
Potawatomie Indian woman using heddle loom in weaving.

thorities do not agree. There is, however, much evidence that weaving was the first method used by man, and it is still the most important, as there is practically no limit to the variety of fabrics that can be produced by weaving. These include all types from sheer chiffons to heavy blankets and rugs.

Weaving. Weaving is a method of fabric construction in which at least two sets of yarns are interlaced at right angles. Primitive people wove from grasses and strips of bark. Today, yarns of every fiber which we have learned to use in cloth are woven.

The manner in which the sets of yarns are interlaced determines to a great extent the characteristics of the cloth; and a specific manner of interlacing is known as the weave. For convenience in discussion the weaves are grouped under the following heads: plain, twill, satin, figure, gauze, double, pile, spot, swivel, and lappet.

Plain, twill, and satin weaves are considered the basic or fundamental weaves, as every other weave includes one of these as a basis or foundation. Many variations and combinations of the groups mentioned are found in novelty fabrics,

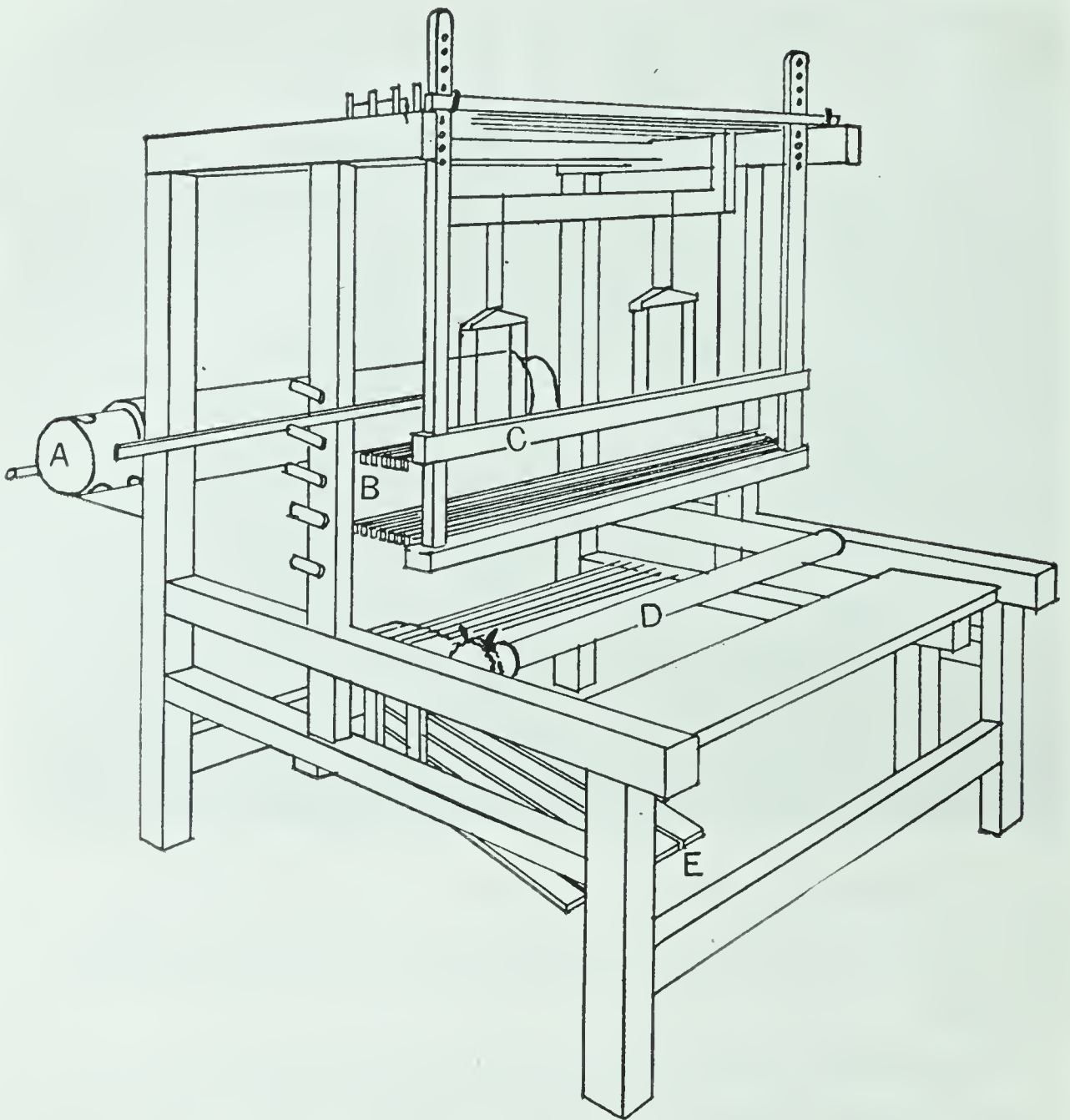


Japanese hand loom.

but each variation cannot be handled separately in this discussion.

Some method must be devised by which one group of yarns, known as the warp, is held in a parallel manner so that another yarn, the weft or filling, may be interlaced at right angles to these. In early times the warp yarns or strands were fastened to objects on the ground and lifted separately as the filling was passed under or over them. Later they were fastened to a stick or pole and hung in an upright position which permitted an easier interlacing of the filling yarns. Speed was developed by perfecting methods for lifting the warp yarns in groups.

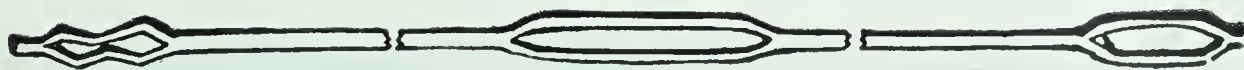
The loom. Gradually, improvements of these methods brought about the evolution of the loom. In many parts of our country hand looms, which typify methods of weaving one hundred years old, are in use. In the large factories, how-



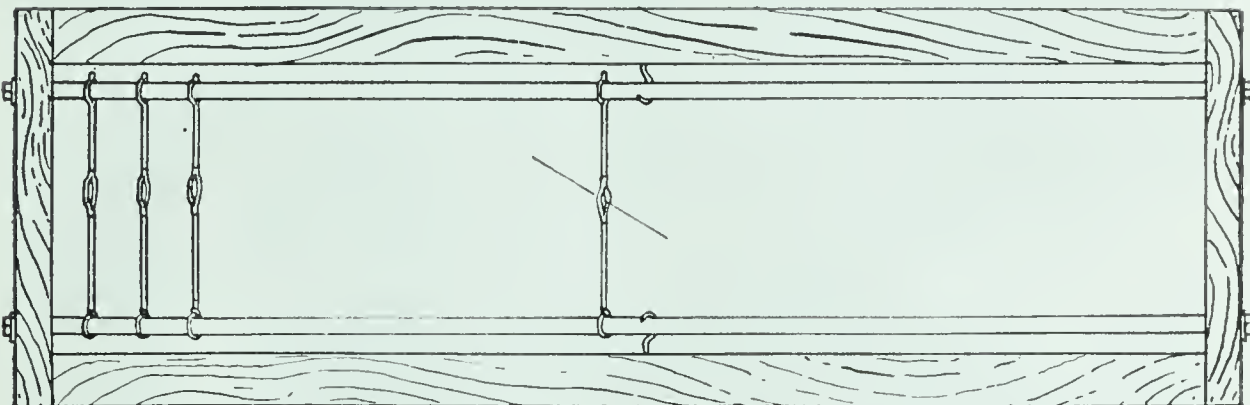
Drawing of simple loom, showing important parts. A, warp beam; B, harness; C, reed; D, cloth roll; E, foot pedals.

ever, automatic stop-motion power looms carry on the quantity production of fabrics which has revolutionized the textile industry. Whether the loom is hand or power driven, certain provisions must be made for interlacing the two sets of yarns at right angles. Though the loom may be elaborated by various mechanical devices, fundamentally these provisions remain the same.

The warp yarns are wrapped in parallel order on a cylinder, called a beam, generally placed in the back of the loom (See



A heddle.

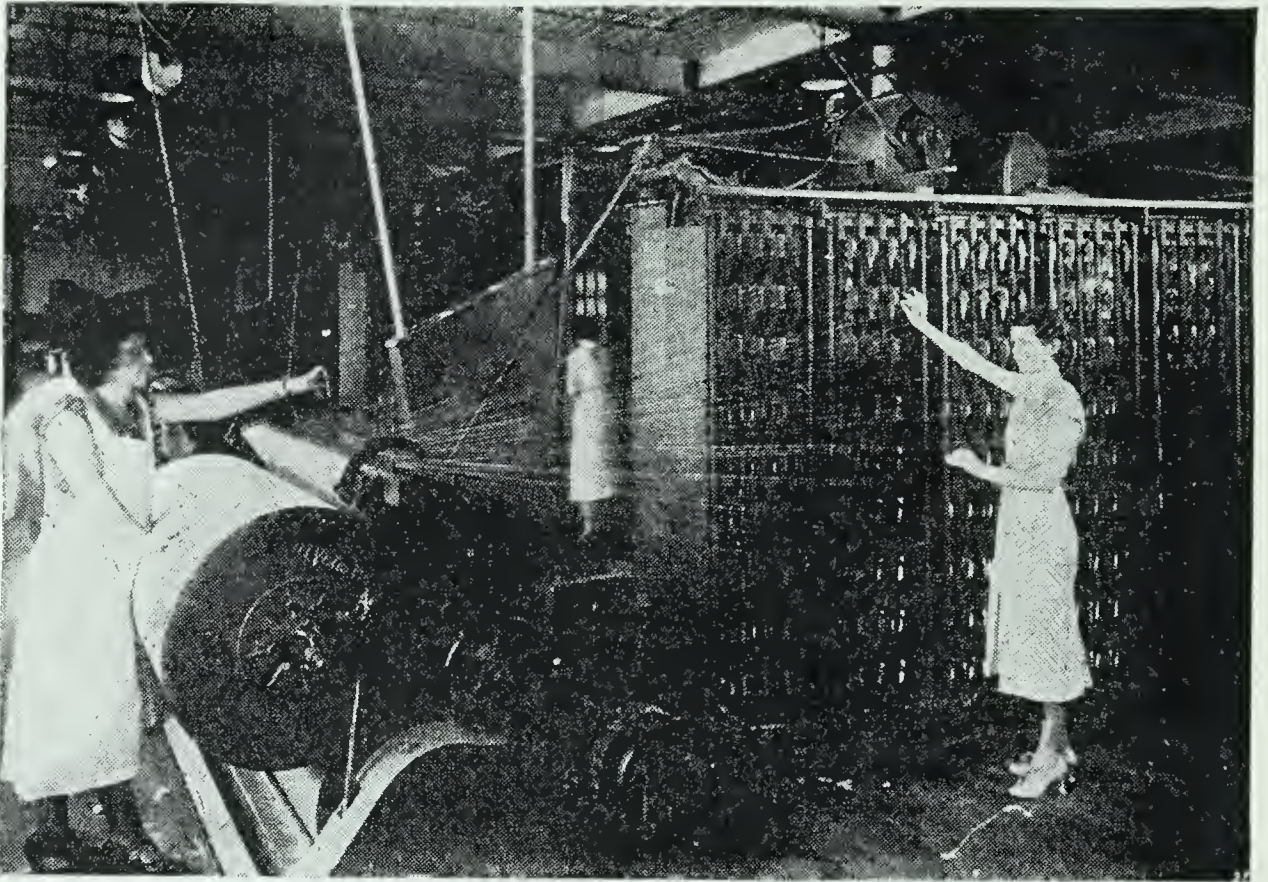


The harness, consisting of heddles and the frame.



Courtesy Callaway Mills, LaGrange, Georgia

“Drawing in” harness frames. This laborious process of drawing each warp yarn through a separate eye is necessary when a new pattern is to be “set up” in a loom.



Courtesy U. S. Department of Agriculture

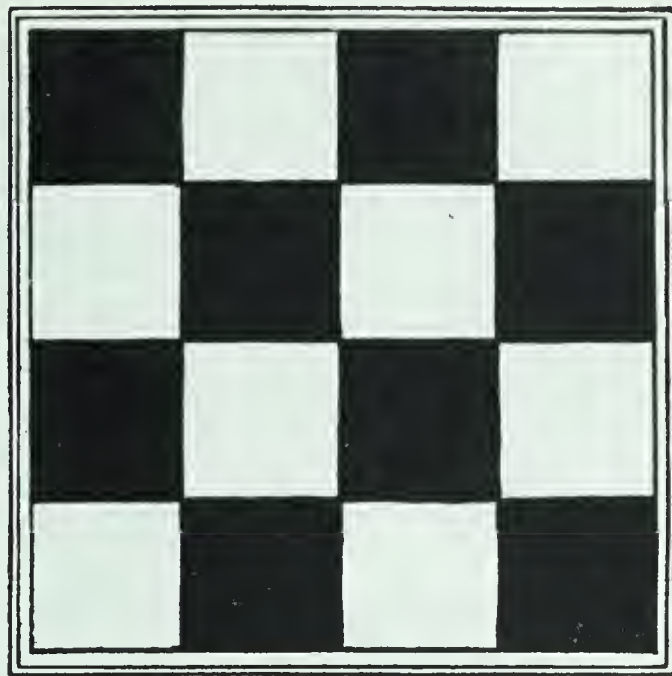
Warper. Threads being wrapped onto a beam.

page 16). From here the yarns pass to the front of the loom, where they are attached to the cloth roll. These yarns are lifted by means of the harness consisting of a series of wires known as heddles and the frame to which they are attached. Each heddle contains an eye through which one or more warp yarns pass. (See the illustrations on page 17.) In preparing a design for use on any loom the pattern is worked out on graph paper and the warp is drawn in according to a predetermined pattern. (See first picture on page 19.)

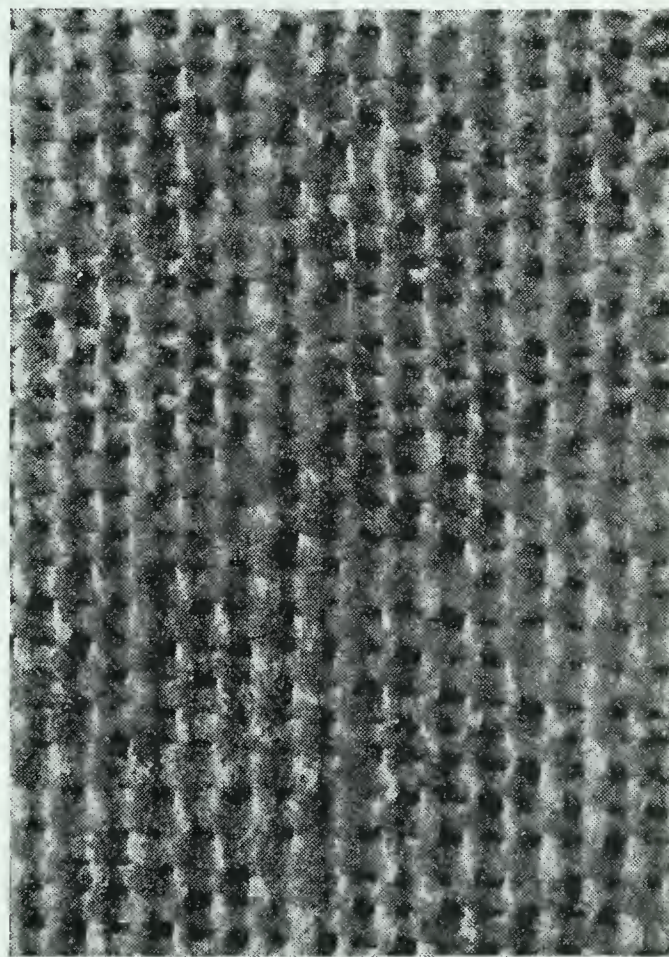
PROBLEM 3. HOW DOES VARIATION IN THE INTERLACING AFFECT WOVEN MATERIALS?

Plain weaving. Plain weaving (See page 19), the simplest form, consists of an alternate interlacing of the warp and filling yarns, one warp up one down the entire width of the fabric. The simple darning of a stocking is, in fact, an example of plain weaving. The foundation, or warp yarns, are

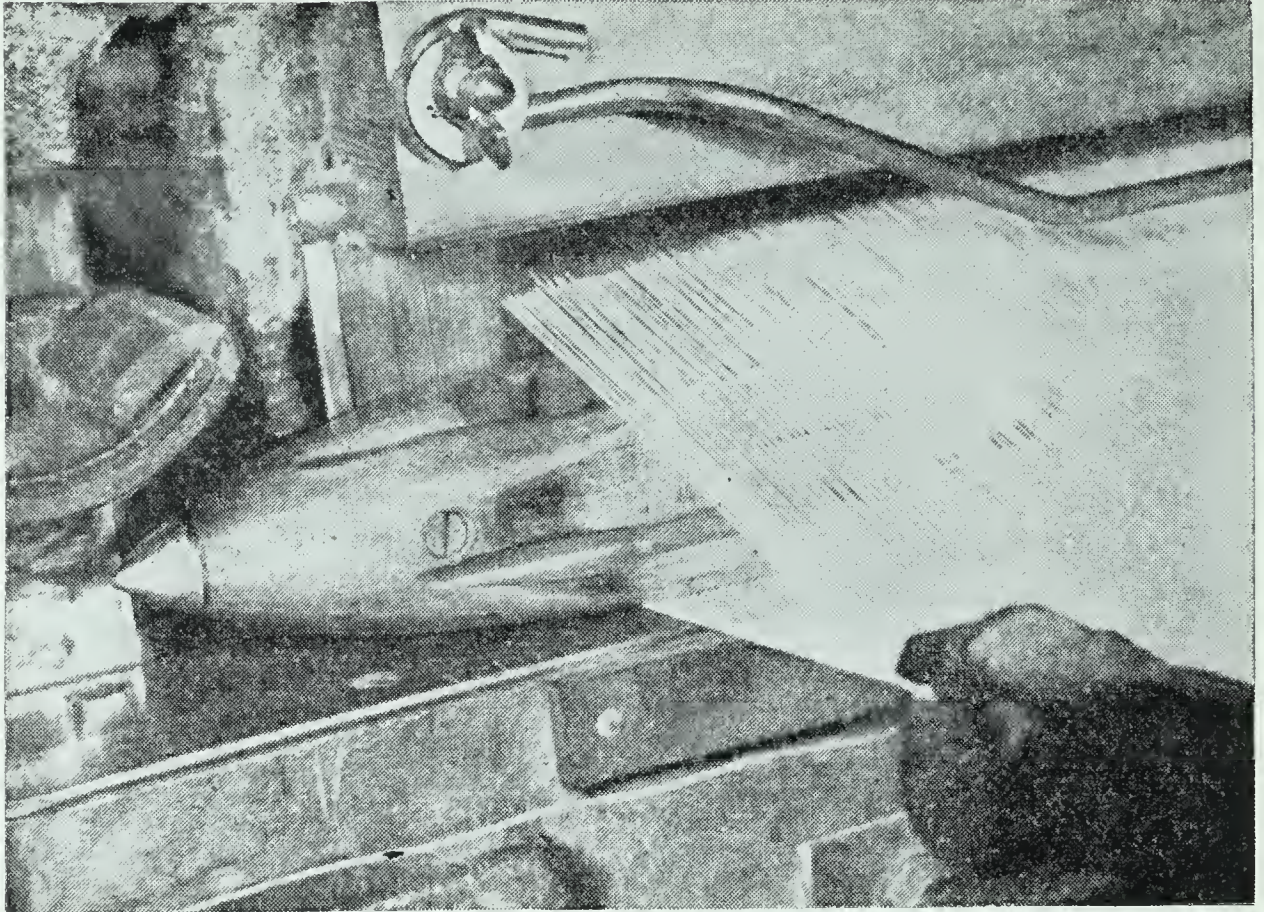
set up in parallel order lengthwise of the hole, and the needle acts as a shuttle carrying the filling which is interlaced under one and over one of the warp yarns. This weave, which is often spoken of as homespun, cotton, or tabby weave, is found in muslin, gingham, crepe, taffeta, and other fabrics. The simplest loom for the construction of a plain weave has two harnesses. Alternate warp ends are drawn in through the heddle eyes of one harness, and the remaining warp ends are drawn in through the heddle eyes of the other. In weaving, one harness is lifted in order to separate the warp yarns and form a shed, through which a shuttle carrying the filling is passed. (See page 20.) Next the harnesses are reversed, the one that was lifted is lowered and the other raised to form a new shed for the backward passage of the shuttle. From this you will see that it is always the warp yarns that are shifted and that the fill-



Plan for drawing in warp for plain weave. Shaded areas indicate warp up and would be drawn in harness one; empty areas indicate warp down and would be drawn in harness two.

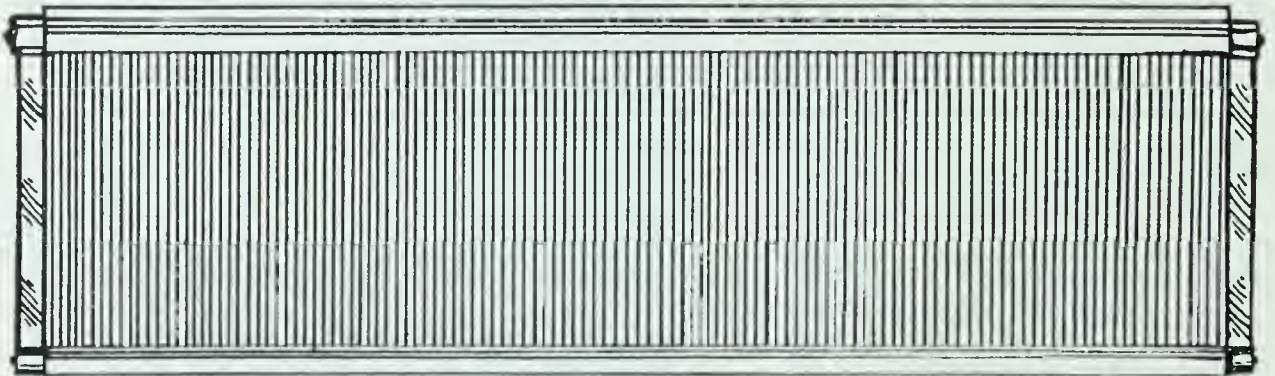


Plain weave.



Courtesy Crompton and Knowles Loom Works

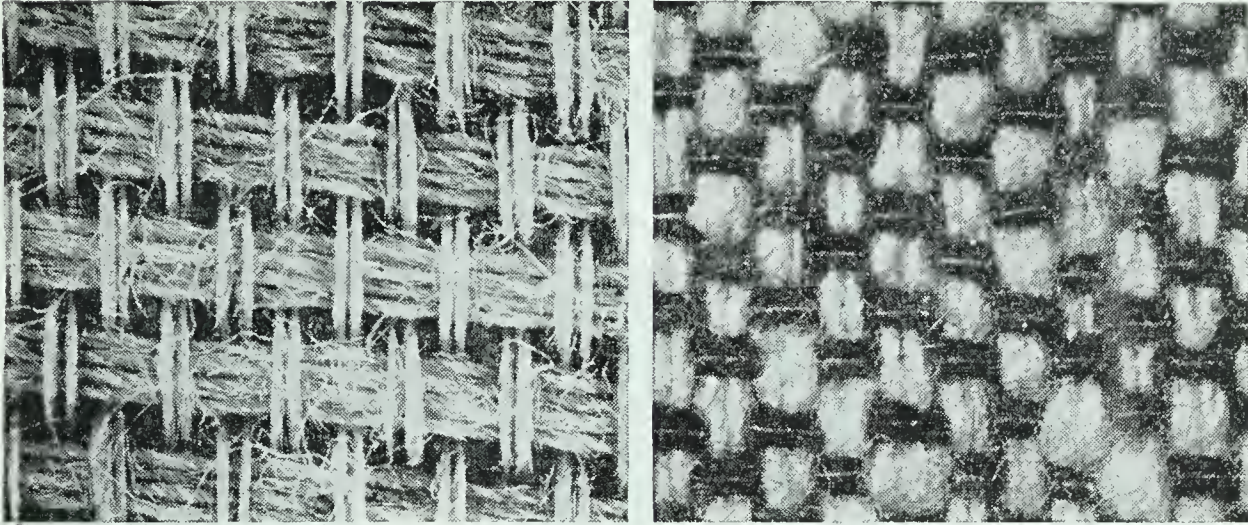
Shuttle passing through the shed of yarns in the process of weaving. The shuttle moves at the rate of about 50 feet per second.



A reed.

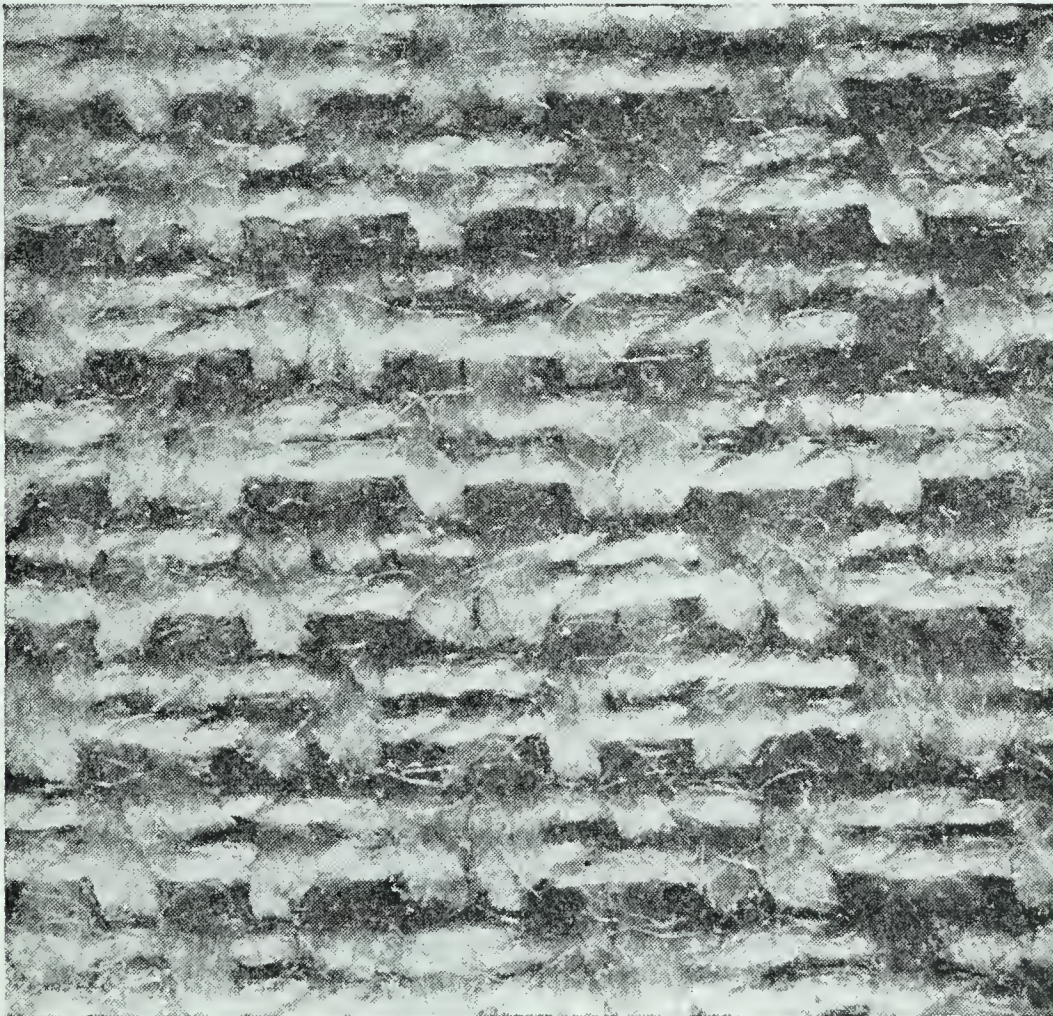
ing yarns pass straight through. After every shot of the shuttle through the shed, and as the harnesses are changing position, the filling is pressed back into place by means of the reed. (See the illustration of a reed on this page.)

Plain-weave fabrics have no right or wrong side due to construction. These materials furnish a great opportunity for variation as the result of a combination of colors, of dif-



Courtesy U. S. Bureau of Standards

Left, basket weave 2 and 4; right, basket weave 2 and 2. (The two black filling yarns are less distinct than the two white warp yarns.)



A form of interlacing usually sold as basket weave.

ferently spun yarns, of differently grouped yarns, and of different fibers. More detailed discussion of this is given in Unit Five, "How Design Is Obtained in Fabrics." A plain

weave offers greater resistance to breaking strain than any other weave constructed of the same yarns with the same number of warp and filling yarns per inch. This is probably due to the added resistance produced by the many interlacings.

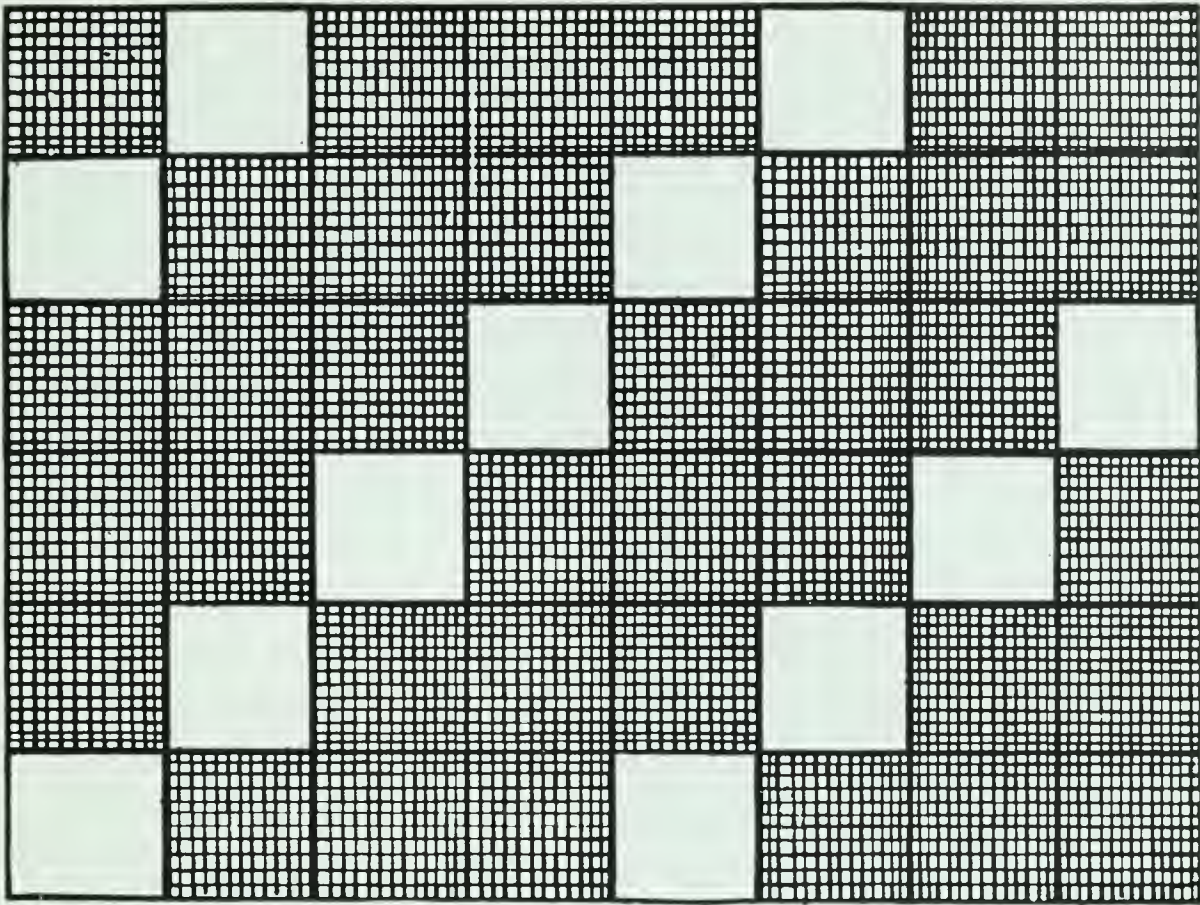
Basket weaving. Basket weave is a variation of plain weave, not a separate weave. In this, two or more yarns in either or both warp and filling are treated as one and interlaced as in plain weave. (See page 21.) This type is found in monk's cloth, used for draperies, and in materials suitable for sport coats or suits.

A loom containing a limited number of harnesses may be controlled by means of a dobby or a cam. A cam is a revolving disk of irregular shape fixed on a shaft which imparts alternating motion to a rod or block engaging with it. By this arrangement a few harnesses may be raised and lowered as desired. This makes possible such variation in the interlacing of the two sets of yarns as to permit the production of the different simple weaves.

Rep weave. Rep weave is another variation of plain weave. In this type of fabric a definite crosswise rib effect is produced, usually by means of a coarse filling yarn. A variation of this is sometimes found where fine yarns alternate with coarse yarns in both the warp and filling. The yarns are so arranged that a pronounced, bold rib is formed across the cloth.

Twill weaving. Twill weaving is a type in which the interlacing of warp and filling yarns is done with a progression of one at the point of interlacing of these yarns. That is, the point of interlacing moves over one warp yarn each time the filling is interlaced with it. Thus if the warp yarns 2, 3, 4, 6, 7, and 8 are up and warp yarns 1 and 5 are down when the first filling yarn is passed through them, the warp yarns 1, 3, 4, 5, 7, and 8 will be up and 2 and 6 will be down when the second filling yarn is passed through, and so on as shown on page 23.

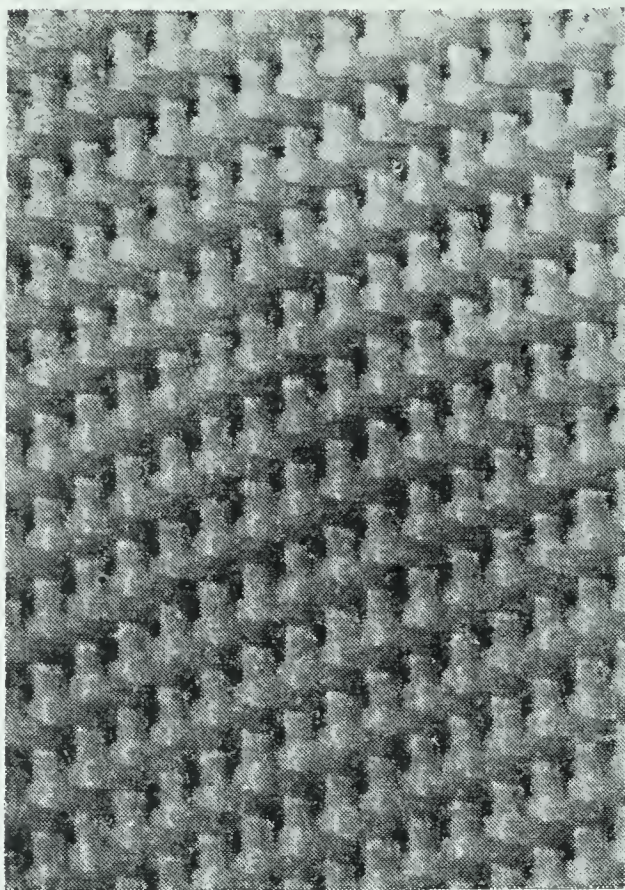
A simple twill weave is made by forming the shed so that two warp yarns are up and one down, so arranged that the



Plan for four-shaft twill weave. Three warp up and one down—written thus: $\frac{3}{1}$. In all illustrations the shaded areas represent warp yarns.

yarns lifted are always one over each time the shed is changed. This requires three shifts of the loom to complete one unit of the design. Either warp or filling may be up and thus form the face of the cloth, and the progression may be to the right or to the left.

Tightly twisted yarns are often used to bring out the diagonal effect and this, with the compact manner of construction, results in a strong, firm cloth. The diagonal effect, whether plain or varied, is decorative and makes an effective self trim. The construction of simple twills from tightly twisted yarns results in fabrics which prove practical for garments to be given hard wear. Yarns that go over several of those of the opposite set form long floats. Material having long floats lends itself to napping, that is, the drawing of ends of fibers to the surface of the fabric as in flannel; hence, twill weaving is used in the better grades of napped goods.



Courtesy American Enka Corporation

Twill-woven fabric.

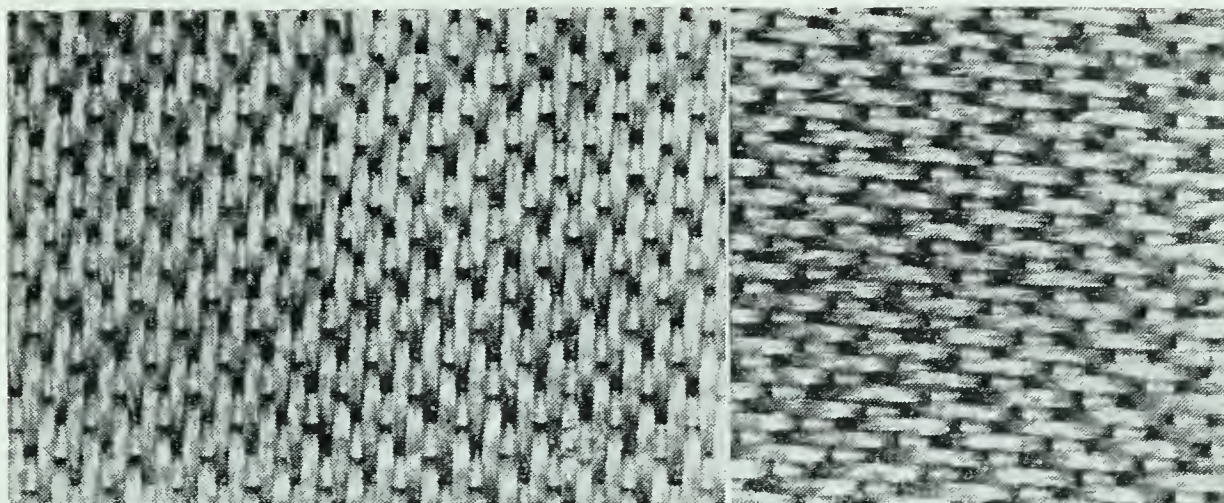
versed; here the filling floats on the surface. Cotton fibers are usually used where this form is found. To obtain the desired effect, a slightly twisted yarn in which the fibers lie practically parallel is thrown to the surface. The number of yarns that are passed over in forming the weave, plus the number of yarns used in the interlacing, is known as the shaft. A five shaft, the lowest number possible in a true satin, is four up and one down. A lower shaft would result in a broken twill. (See the diagrams on page 25.)

The wearing quality of satin-woven fabrics is largely determined by the length of the float. The length of the float is determined not only by the shaft used but also by the number of yarns per inch. Thus, in a five-shaft satin, where the warp yarn is bound down by every fifth filling yarn, the float would be much shorter in a fabric having 100 filling yarns per inch than in another five-shaft satin having only 50 filling yarns per inch.

Figure weaving. Figure weaving is that type in which a de-

Satin weaving. Satin weaving is the irregular interlacing of warp and filling yarns with a regular progression of more than one. By this system of interlacing the diagonal effect is broken, producing a smooth surface with a characteristic luster.

In satin weave the warp floats over several filling yarns; thus the warp is thrown to the surface. Silk, rayon, or linen fibers are usually used when this method of interlacing is found. (See page 25, top.) Sateen weave is a variation of satin. In this weave the manner of interlacing is re-



Courtesy American Enka Corporation

Left, satin, warp-faced fabric; right, sateen, filling-faced fabric.

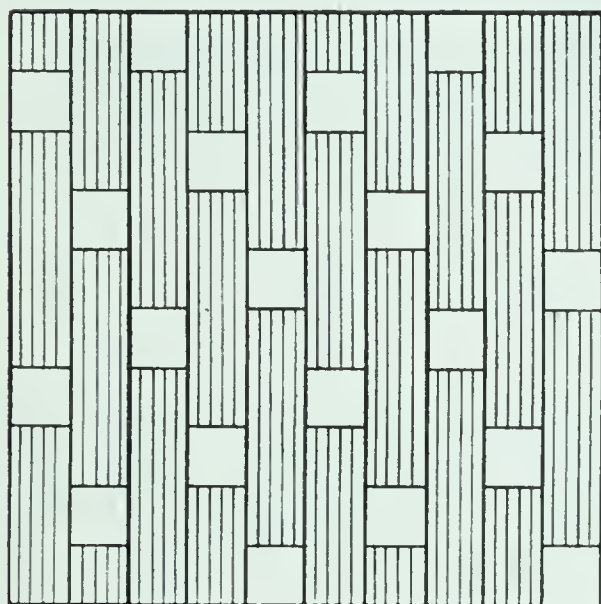


Diagram showing interlacing of yarns that would produce true satin.

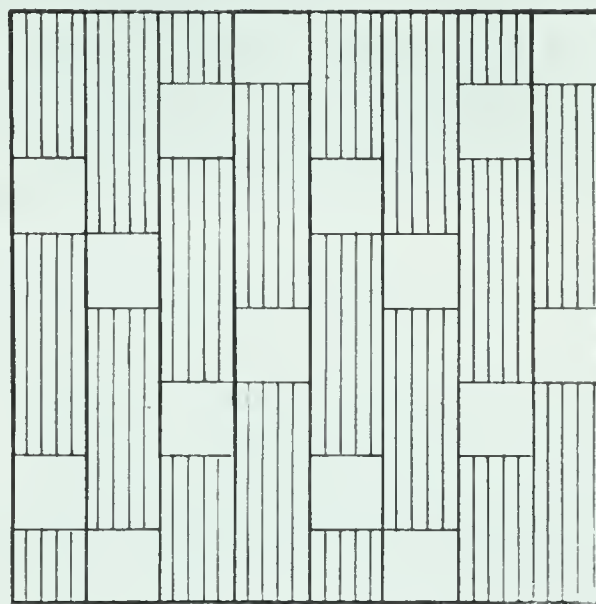
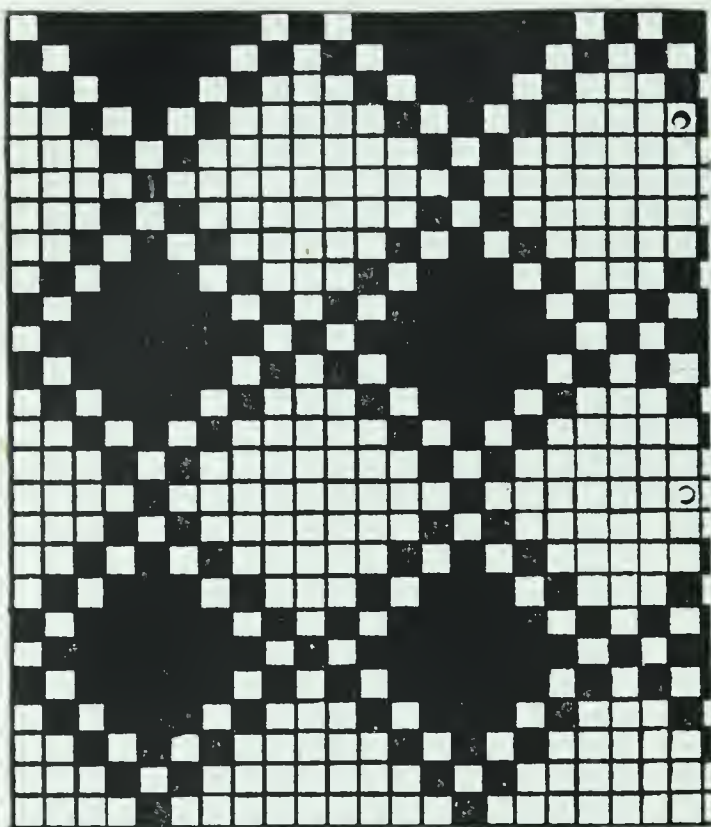


Diagram showing interlacing of yarns that would produce broken twill.

sign is formed by a change in the interlacing of the warp and filling yarns. Only two sets of yarns are used, and the design is woven into the fabric. Simple figure weaves, such as diaper cloth and honeycomb (See page 26), may be woven on the simple loom manipulated by the cam, as has been previously described.

Diaper or bird's-eye designs may be produced by combining right and left twills. A simple illustration is shown on the bottom left on page 27.



Drawing-in draft for honeycomb weave.

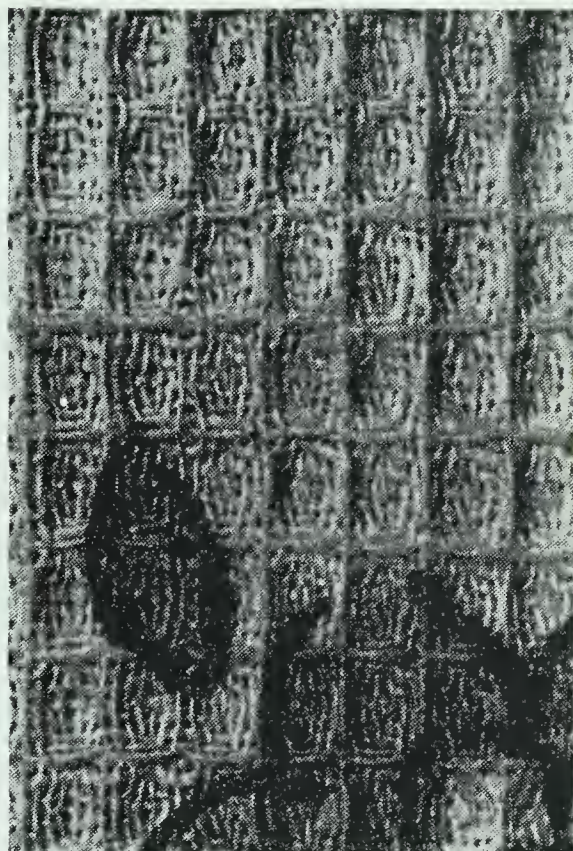
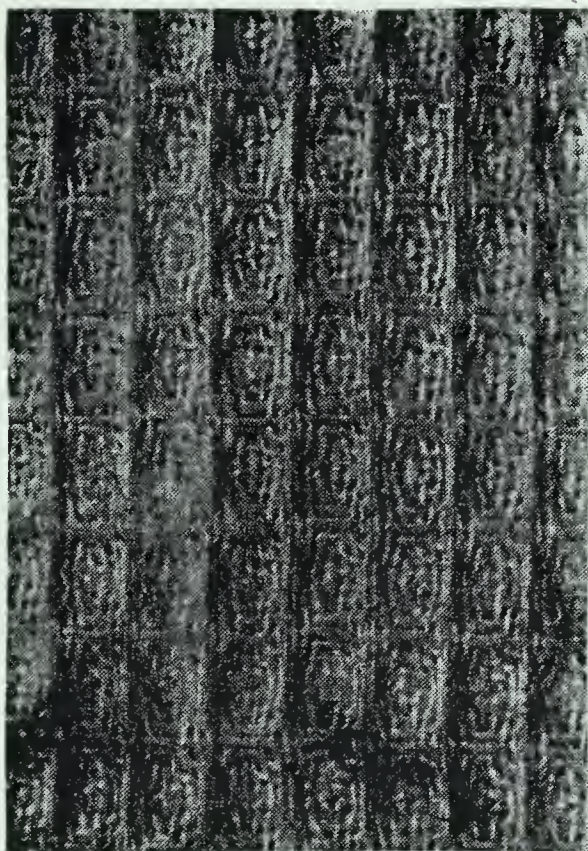
In honeycomb weaves the cell-like appearance is produced by the floating yarns which form ridges.

The plain weave along the edges of the draft results in a tightening of the yarns and the formation of cell-like depressions. Although the diamond construction is used, the design in the fabric has the appearance of a rectangle. In this class of fabrics both the warp and filling yarns float on both sides

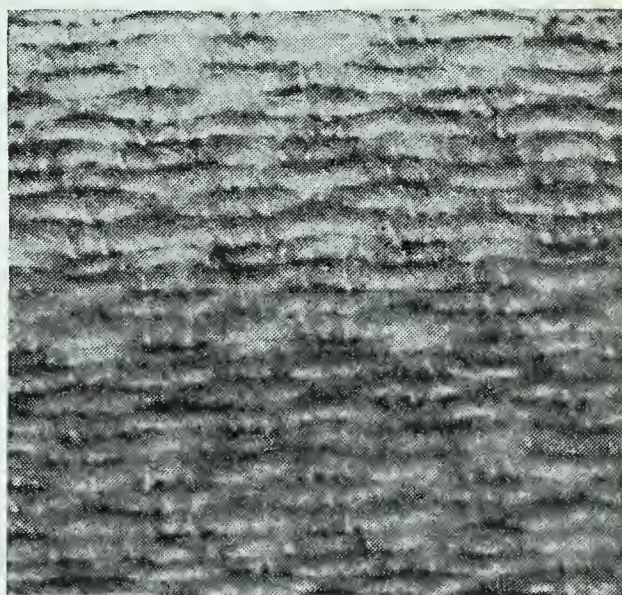
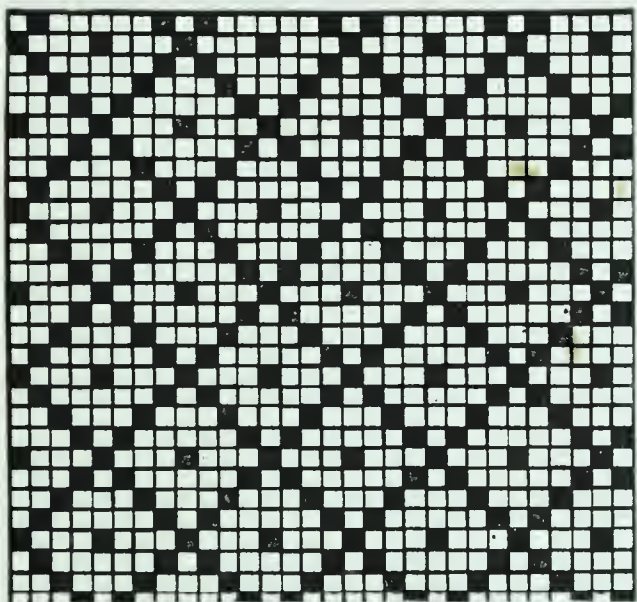
of the material. This gives a structure suitable for towels. The accompanying diagram and illustration show the method of interlacing. (See illustration above and those at top of page 26.) The floating yarns forming the ridges are too short to lie smoothly when they are interlaced the number of times required in forming the cell-like portion.

Figure weaving is one of the most popular means of creating design. Most piqué fabrics are examples of figure weaving. One filling yarn weaves on the face of the cloth for the space of one stripe and then floats on the back for the same distance. The next filling weaves and floats alternately but on the opposite ridges from those of the first filling. Only two sets of yarns are used in the weaving, although stuffer yarns may be used in addition to make the ridges more prominent. (See page 28.)

A variety of colors and different types of yarns may be combined in order to emphasize the design. Examples of elaborate and beautiful fabrics produced on simple hand looms are among the native materials of every country. Simple designs in figure weaving, such as bird's-eye and honeycomb, were varied or combined in the production of bedspreads and other

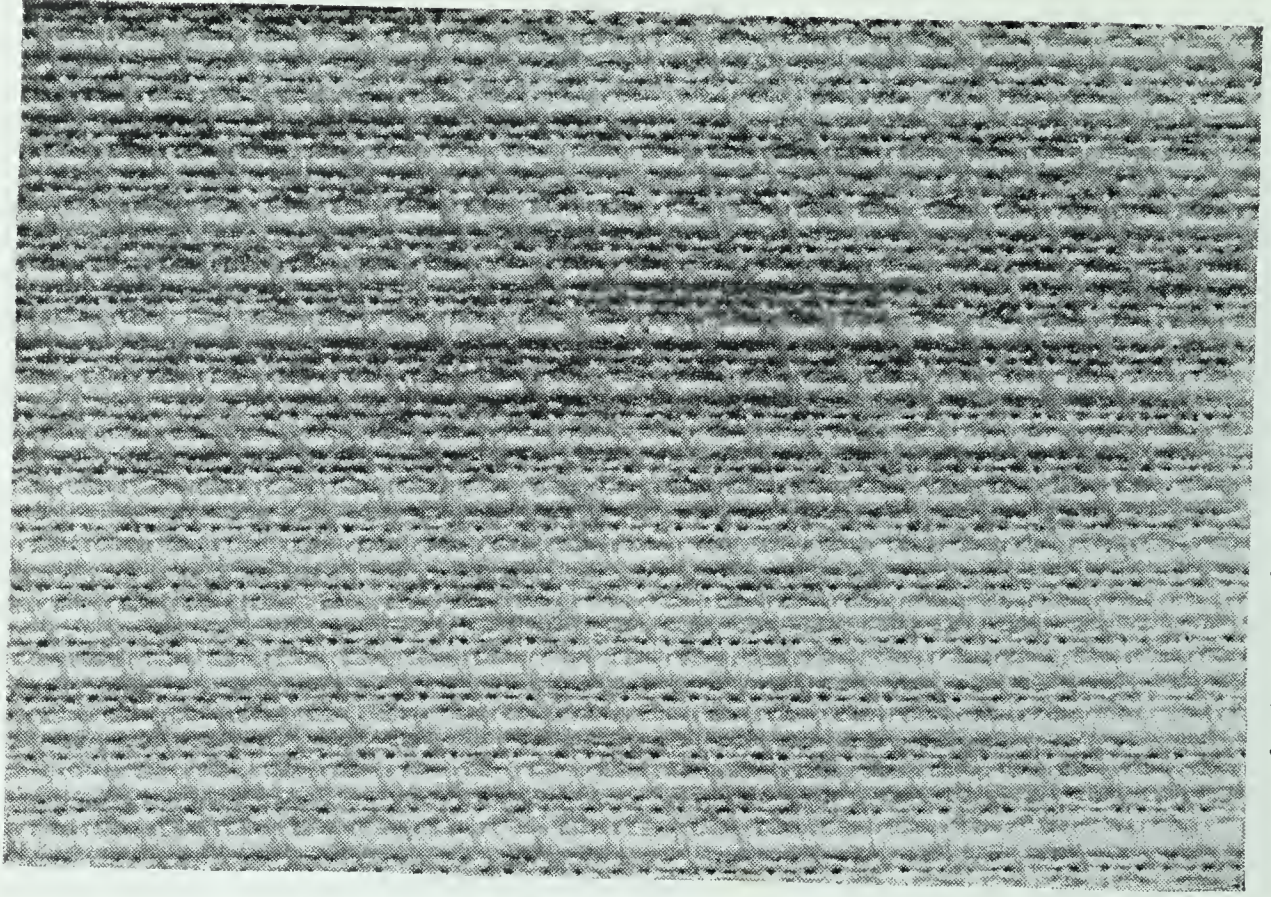
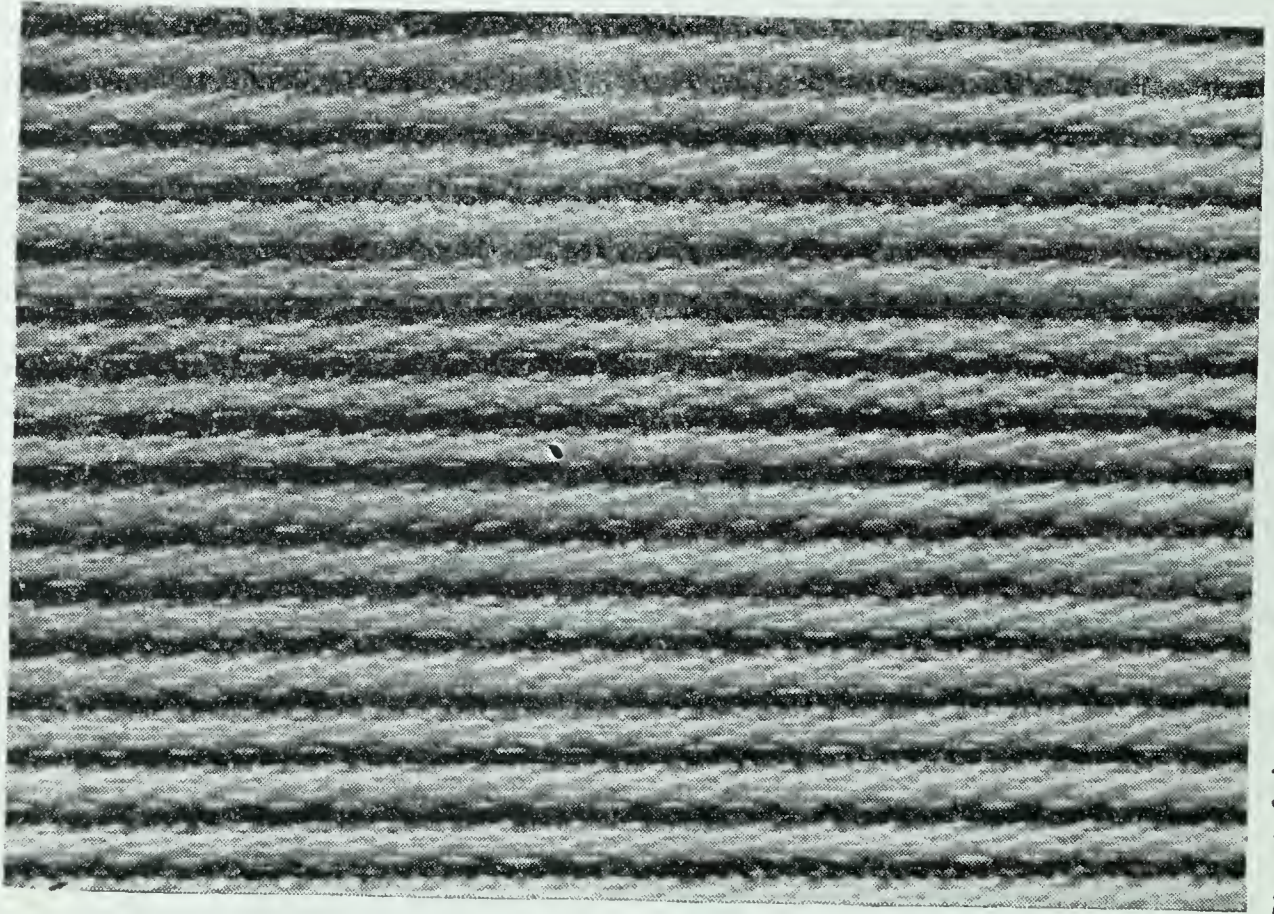


Honeycomb cloth. Left, back of cloth; right, front of cloth.

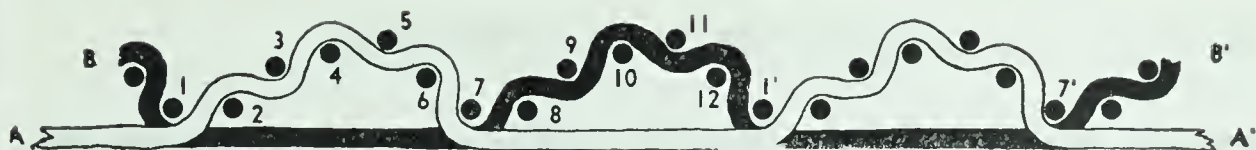


Drawing-in draft for bird's-eye weave.

Bird's-eye cloth.



Piqué fabric in which two sets of yarns produce the design by a variation in the interlacing. Left, face; right, back of cloth.

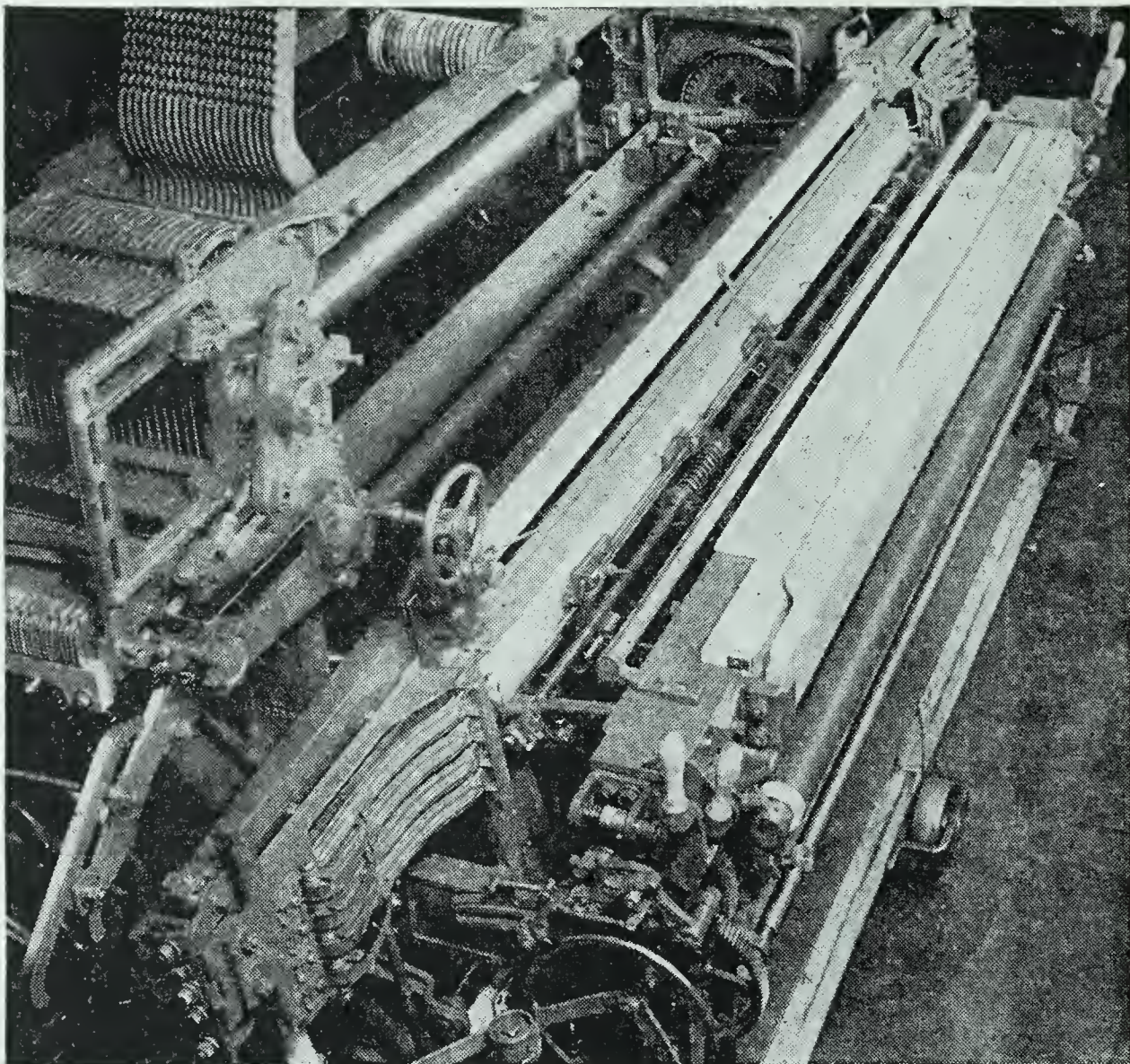


From Posselt's *Technology of Textile Design*, published by McGraw-Hill Book Co., Inc.

Diagram of a rib fabric in which every pick alternately floats on the back and interlaces with the warp in a plain weave on the face of the cloth.



Hand-woven coverlet in blue and white.

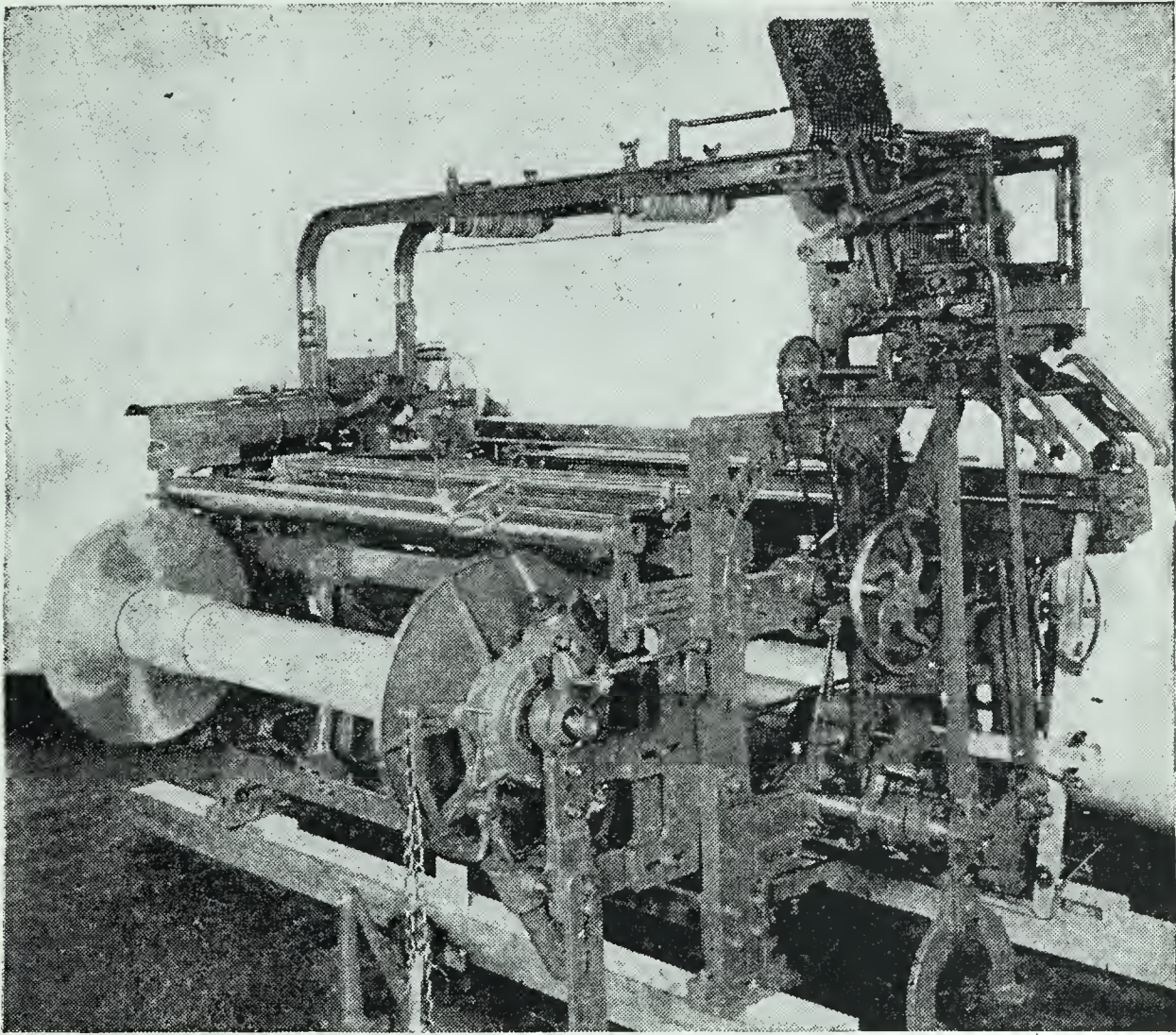


Courtesy Crompton and Knowles Loom Works

This illustration and the illustration on the opposite page show the application of the dobby to a loom. By means of the dobby, elaborate designs may be produced.

homespun of American colonial days. (See page 29.) Many of these designs are being copied today both in hand weaving and factory production.

To produce figure weaving in a complex design on a power loom requires some other method for handling the many harnesses needed to develop the pattern. This need is met through the replacement of the cam by an arrangement known as the dobby. (See pages 30, 31.) One type of dobby consists of strips of wood containing pegs so arranged that the



Courtesy Crompton and Knowles Loom Works

This illustration shows the application of the dobby to a loom. The dobby shown here is quite different from the simple type described.

pegs come in contact with levers that govern the harness. A strip of wood is prepared for each pick or filling thread in one repeat of the design, and a peg is inserted whenever the warp yarn is to appear on the surface of the fabric. Different designs may be woven without changing the manner in which the warp yarns are drawn into the harness, by merely changing the position of the pegs in the strip of wood.

The more elaborate designs are carried out by means of the Jacquard, an attachment by means of which each warp yarn is controlled as desired. (See page 586 for further discussion of the Jacquard.)

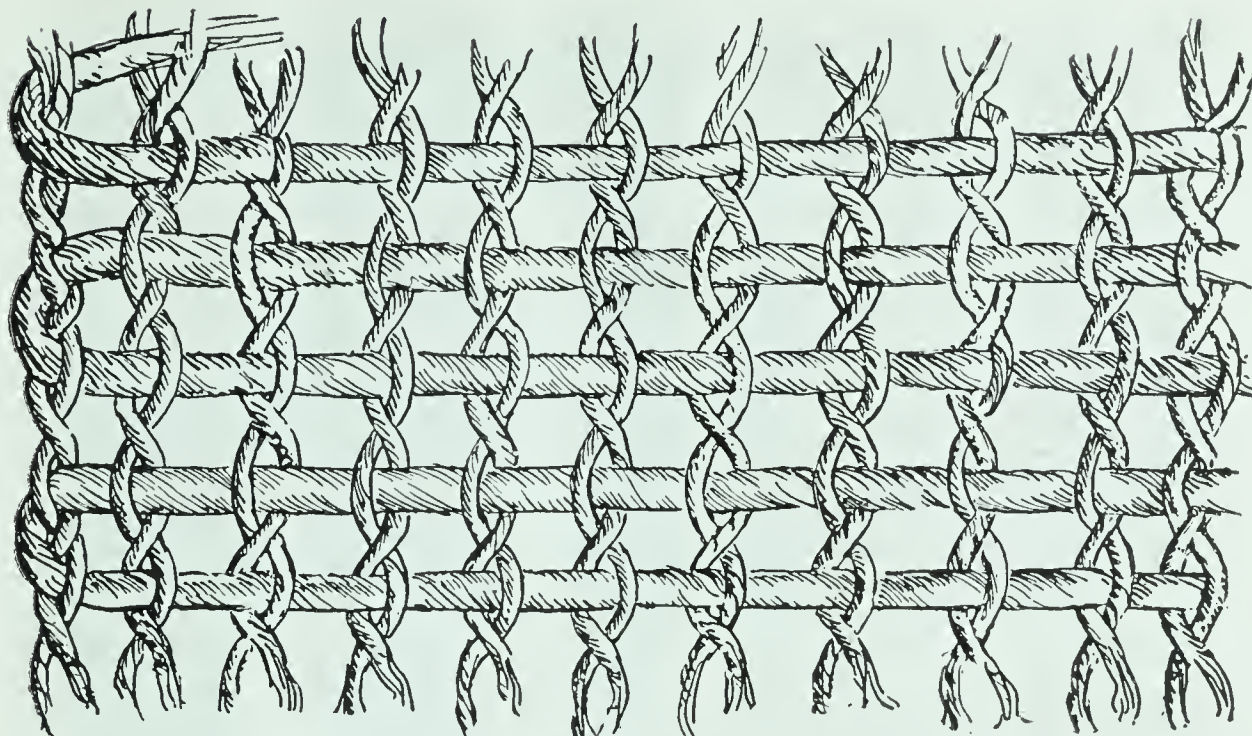
The Jacquard is used in the production of damask and

other staple fabrics characterized as figure weaving, as well as for brocades. The working out of a design for a Jacquard and the drawing in of the warp yarns are slow and intricate processes and, unless used for quantity production, they become important economic factors in the cost of the product. This accounts in part for the high price of novelty fabrics of which only a limited number are desired on the market.

Gauze or leno weaving. The terms gauze and leno may be used synonymously to designate any fabric in which the doup principle of weaving is used. This principle of weaving employs a doup or slip arrangement to cross certain warp yarns. The crossed yarns are bound in by the filling yarns when in the crossed position. All of the warp yarns may be brought from one beam. However, frequently, the difference in take-up makes it necessary for the crossing and standard warp to be brought from separate beams.

The doup, or slip, which is really a half heddle, may be so placed that the crossing of the warp is always above the standard warp, but bottom douping is more common and easier to apply to the loom. The crossed yarns always stay either above or below the standard warp, never changing from one to the other. While out of the parallel position the filling yarn is so interlaced that the warp yarns are held in place; they are then returned to their normal position and another pick or filling yarn is inserted. This change of the position of the warp yarns by the crossing back and forth prevents the filling yarns from lying close together. Thus, the fabric is given an open-mesh appearance and at the same time the warp yarns are held firmly in place so that there is little or no slippage. (See page 33.)

A distinction is sometimes made between gauze and leno in that the term gauze is applied only to fabrics in which the crossed interlacing results in a light, open-mesh fabric, and leno is applied to heavier fabrics in which the crossing ends form a distinct zigzag effect on the surface of the cloth. In another classification gauze is used to designate those fabrics in which only one filling yarn is inserted between the crossing



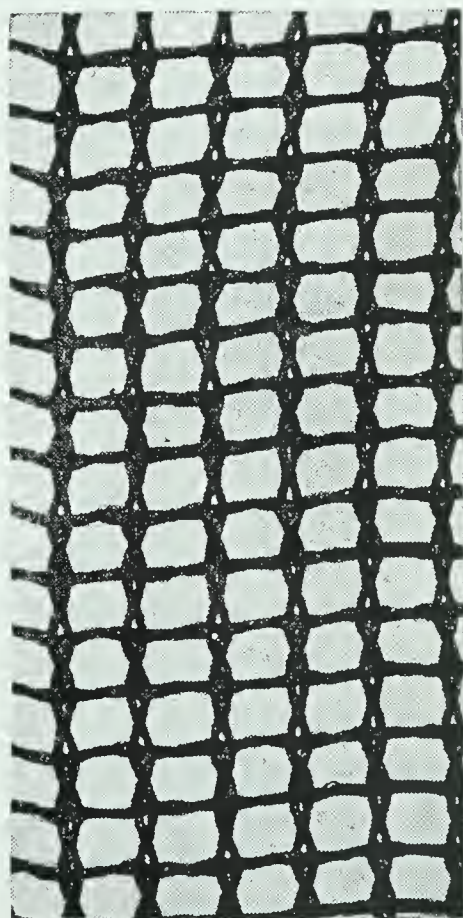
Courtesy Bureau of Home Economics, U. S. D. A.

Gauze weave.

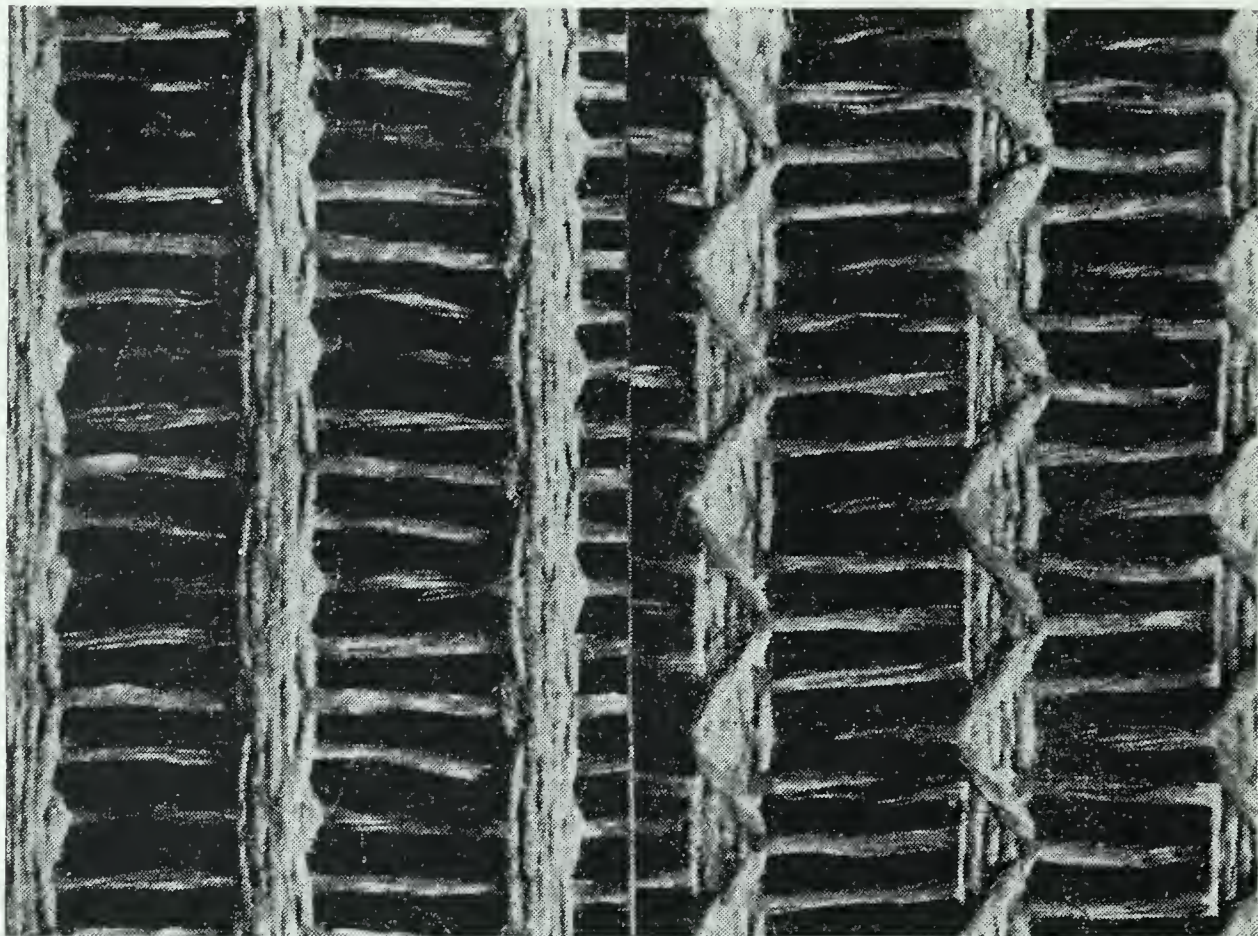
of the warp yarns, and leno is used for cloths in which more than one filling is inserted for every crossing of the warp yarns. However, the two terms are generally regarded as synonymous, and that usage is accepted here.

A typical gauze fabric is illustrated on the right, where one crossing end passes from side to side of one standard warp and on succeeding picks. The illustration on page 34 illustrates the doup weaving principle in which more than one pick is inserted before the crossed ends are returned to their original position.

Imitation gauze or mock leno is a popular form of weaving by which the open-mesh effect of gauze weaving is obtained without the mech-



A gauze-weave fabric.



Zig-zag effect on the surface of the cloth produced by doup weaving. The face of the fabric is shown on the right.

anism necessary to cross the warp yarns back and forth, as is done for gauze weaving. A study of the diagram on page 35 will show that one or more of both warp and filling yarns float over a group of yarns and by this method hold the groups apart.

Fancy gauze effects or figure weaves may be produced by a combination of gauze weave with plain or other types of interlacing. In the parts woven with plain-weave interlacing, the two sets of warp yarns lie parallel and are treated as one set.

Both gauze and imitation gauze weaves provide a convenient means by which the manufacturers of woven goods may imitate the loose, open structure of knitted fabrics. Many types of novelty cloth are produced with gauze weaving as a basis.

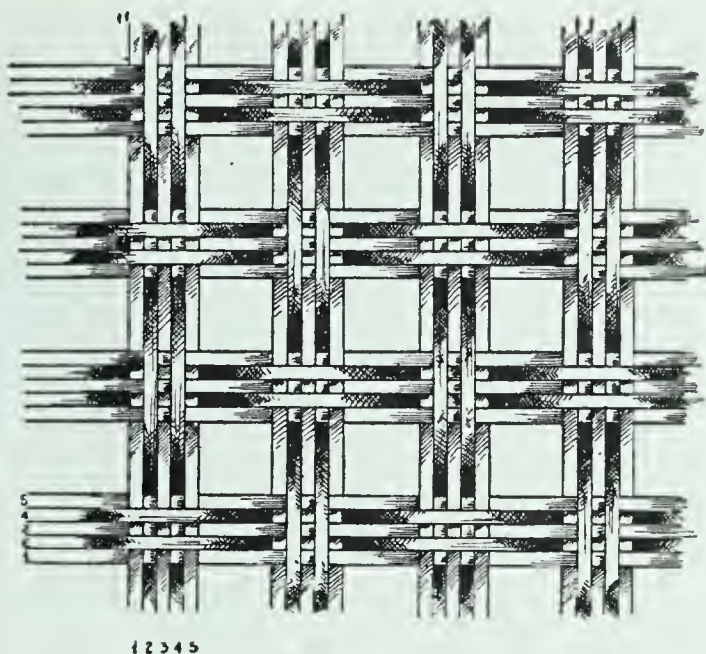
Double weaving. Double weaving involves the use of three or more sets of yarns. The term may be applied to the pro-

duction of a fabric constructed from five sets of yarn, two sets being used on the face and two on the back with the fifth yarn interlacing between them. In other fabrics, only four sets of yarns are used and some of the warp or filling yarns are interlaced with the other set at certain intervals. Backed or double-faced cloth and tubular fabrics in which only three sets of yarns are used for the fabric are also classified as double woven.

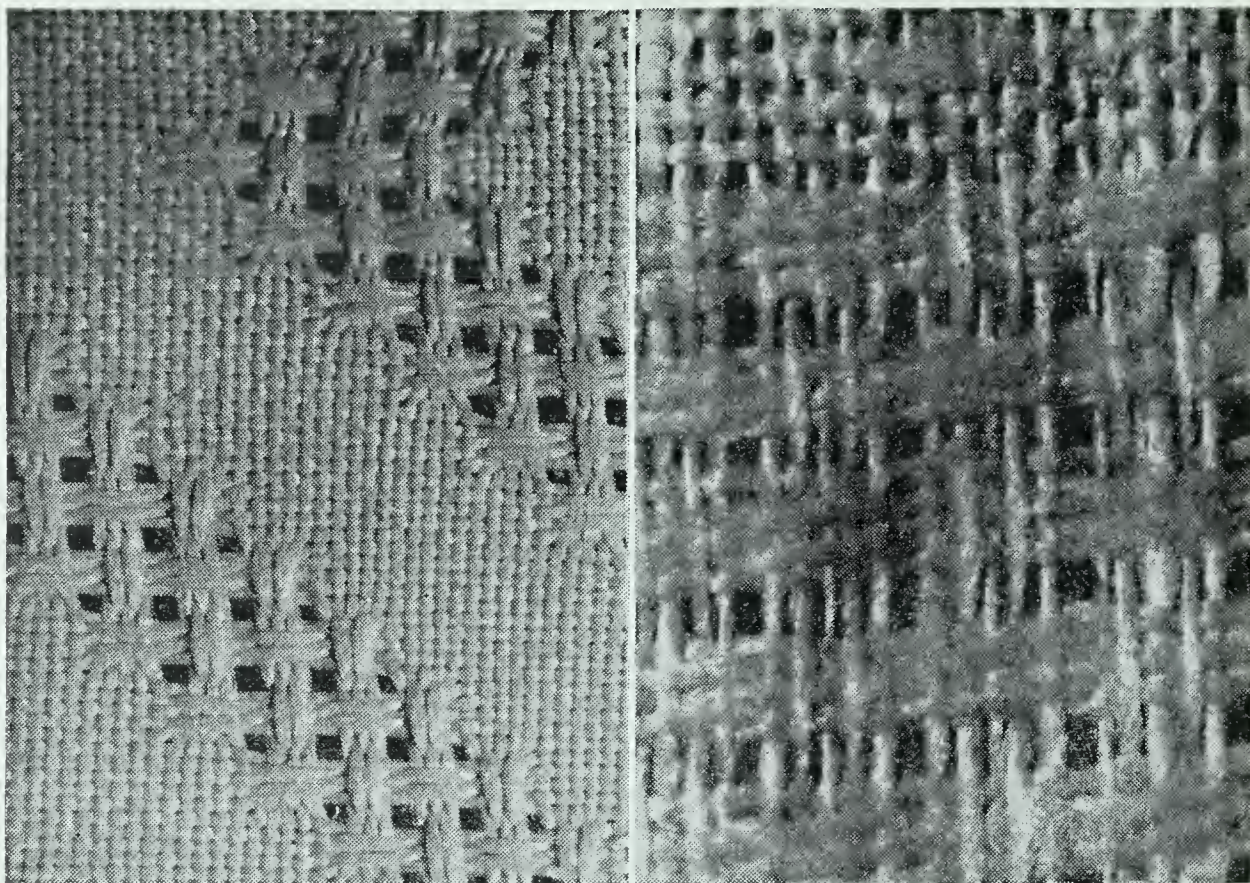
Double weaving is used to produce design in various types of fabrics, to produce backed cloth, double-faced cloth, pile cloth, and to construct tubular fabric.

Double cloths woven from four or five sets of yarns are found in heavy coat materials. These fabrics are usually in plaids or small designs and differ in color and design on the two sides. Fibers of inferior quality may be used in the yarns planned for the back.

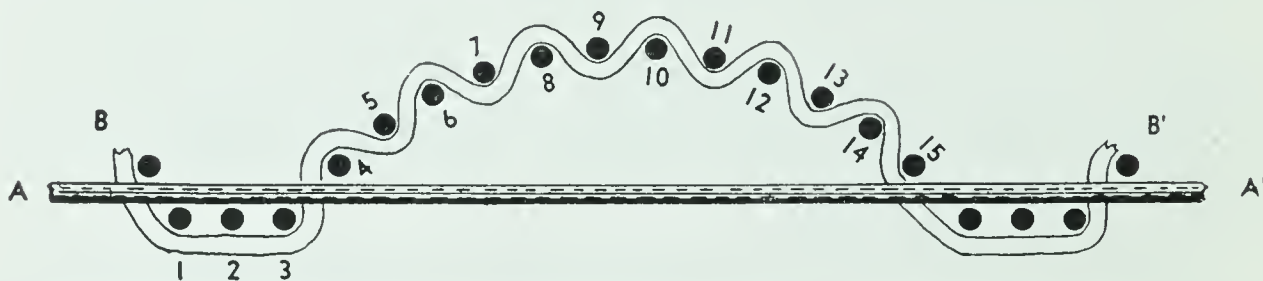
One system of warp and two systems of filling are used in the construction of fabrics either for the purpose of additional bulk or in order to produce unusual design effects. This type is frequently found in heavy woolens and in the construction of cotton cloth for bath or lounging robes. The fine warp yarn does not appear in the design, and the filling yarns differ in color on the two sides, either of which may be used for the face. Two systems of warp and one system of filling yarns are used in the construction of double-faced cloths. This type of construction is employed largely in the production of ribbons and other narrow fabrics used for trimmings. In these cloths two entirely different qualities of material as well as different colors may appear on the two sides of the cloth. An extra set of



Drawing illustrating one method of interlacing the yarns to form mock leno or imitation gauze.



Two clothing fabrics showing use of imitation gauze weave in creating design.



From Posselt's *Technology of Textile Design*, published by McGraw-Hill Book Co., Inc.

Diagram of a rib fabric in which every odd-numbered pick interlaces with 12 warp yarns as in plain weaving (floating below 3 warp yarns), and every even-numbered pick (rib-pick) passes under 12 warp yarns on the back of the fabric and then forms the face rib over 3 warp yarns.

warp yarns may be used as backing in the production of heavy-weight cloth. Fabrics planned for women's wear are often made with two sets of warp yarns in the design. Such types of prominent rib fabrics as overcoating and sport goods may be constructed in this manner.

Matelassé is a type of double cloth in which extra sets of

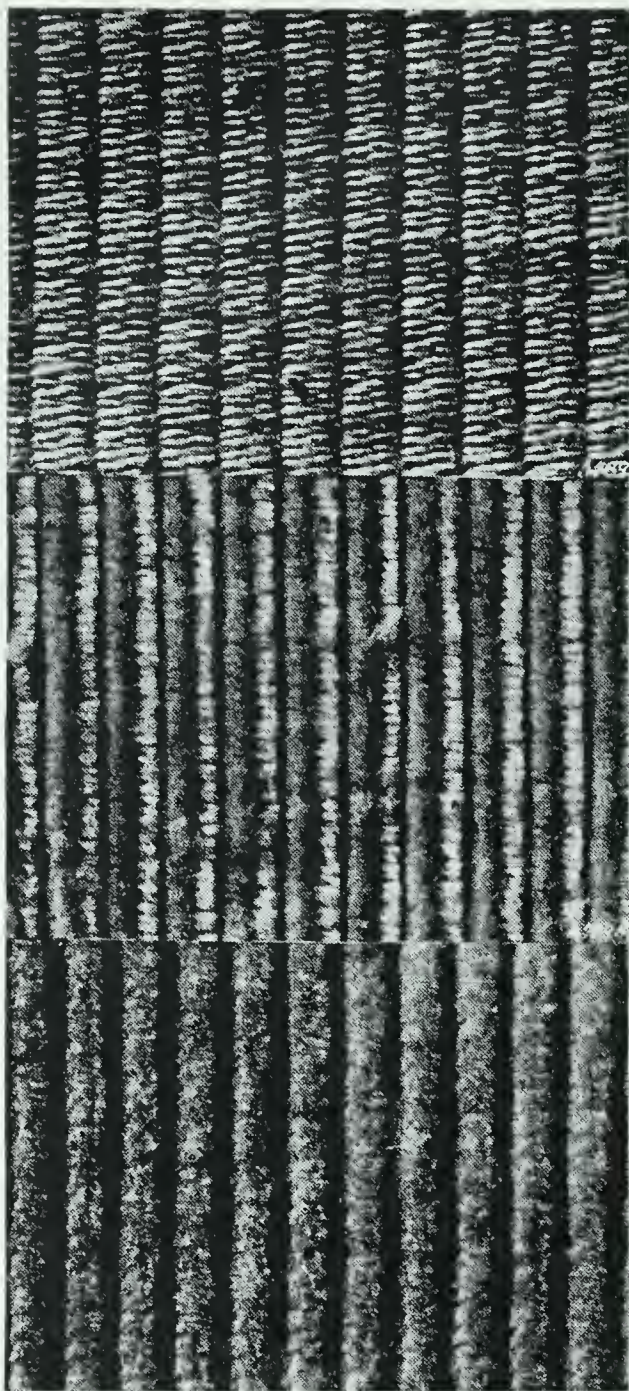


Matelassé. Raised design produced with a third set of yarns.

yarns are used in such a manner as to create puffed effects in design. The yarns used to form the back are tightly twisted and the other yarns have little twist. A design may be formed in stripes where the tightly twisted yarns float on the back and come to the front only between stripes. A combination of yarns of different amounts of twist, yarns of different fibers, and a variation in the weaving permits the production of many elaborate and beautiful cloths.

Pile weaving. Pile weaving is that type of interlacing in which a third set of yarns is introduced in such a manner as to form loops or cut ends on the surface of the cloth. Ordinarily, either a plain or twill weave is used for the foundation or ground fabric. In every pile fabric two sets of yarns are necessary for the construction of the ground and a third set forms the pile. This requires three sets of yarns, either two sets of warp with one of filling or two sets of filling with one set of warp. The greatest variety of fabrics is produced by means of an extra set of warp yarns.

Filling pile fabrics. In filling pile fabrics produced with two



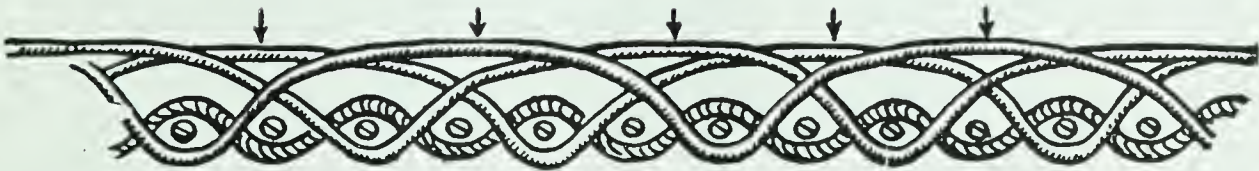
Steps in the manufacture of corduroy. Top, uncut float; middle, cut float; bottom, finished.

sets of filling yarns, a plain or twill weave may be used for the ground. The filling for the pile floats over three, five, seven, or more yarns. The filling floats are cut, either by hand or by machinery, and brushed up to form the pile. (See page 36.) Corduroys are produced by this method.

Velveteens are another type of fabric produced with a filling pile. As in corduroy, one set of warp and two sets of filling yarns are required, but the yarns are interlaced in an all-over effect instead of in rows. A twill weave is used in which the pile yarns float over three to five ends for a short pile, or five to nine for a long pile. The ground yarns may interlace in a plain weave and the interlacing of the pile with the ground may be either "V" or "W." This variation is illustrated in the drawing showing the construction of double

weaving where in the "V" the pile is held down by one filling yarn, and in the "W" the pile is interlaced with three filling yarns. (See the illustration on page 41.)

Both corduroy and velveteen are prepared the same for cutting. Lime or a similar substance is used to give a cutting edge to the fabric and the back is stiffened with starch or glue. In hand-cutting the fabric is stretched on a frame and the op-

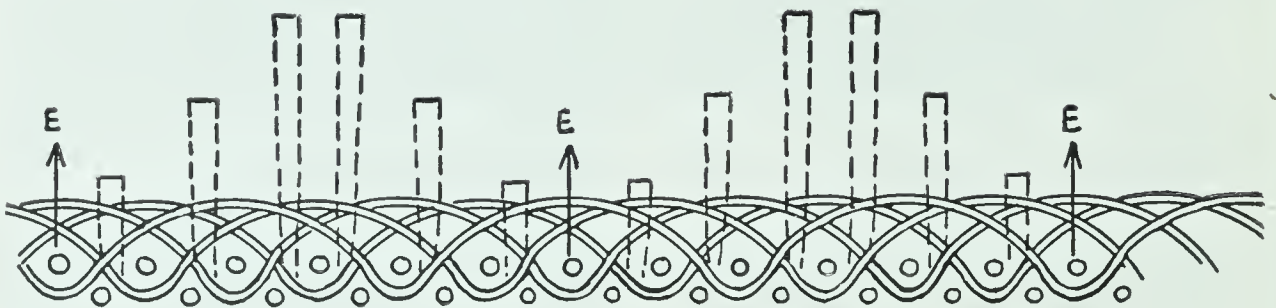


Drawings showing velveteen before and after cutting.

erator uses a thin steel blade with attached guide. The purpose of the guide is to open up the float and hold it in a position to be cut. For machine-cutting, many pieces of fabric are sewed together face side up. The operator must hold the cutting blade against the cloth, which moves under a definite tension. In both hand- and machine-cutting the rows or "races" are cut one at a time the full length of the cloth. There is, however, a machine used for cutting corduroy in which all the cords are cut at the same time. This is by means of circular knives, one to each cord. The fabric moves forward toward the revolving knives, but just before contacting the knives it is taken downward. By means of guides the floating pile picks are brought into contact with the knives and are cut.

Novel effects may be obtained simply by variations in the cutting of plain velveteens. In this way tufts of different lengths that form rounded cords are produced. Different widths of cords may be formed in the same weave, as the width of the cord is not determined by the length of the pile float but by the manner in which it is cut. If a long float is cut to one side of the center, the adjoining cords would be of different widths. (See the illustration on page 40.)

Warp pile fabrics. Warp pile fabrics in which the pile is formed by a warp yarn include a wide range of materials such



Drawings showing method of cutting plain filling pile in such a manner as to form tufts of different lengths.

as velvet produced by the double-weaving method, some types of carpet woven with a warp pile over a wire, and bath towels woven by the terry method.

Pile fabrics formed by double weaving. One of the most commonly used methods for producing pile fabrics is that of double weaving. In the construction of this type, five sets of yarns are necessary. The pile yarns which are warp yarns are interlaced with warp and filling forming one side of the fabric, then pass over and interlace with the two sets of yarns that form the other side of the cloth, then return to interlace again into the first set. This yarn which passes back and forth from one side to the other of the cloth is cut and thus two fabrics are produced, each with a pile of cut yarns on the surface. Velvets are woven by this method.

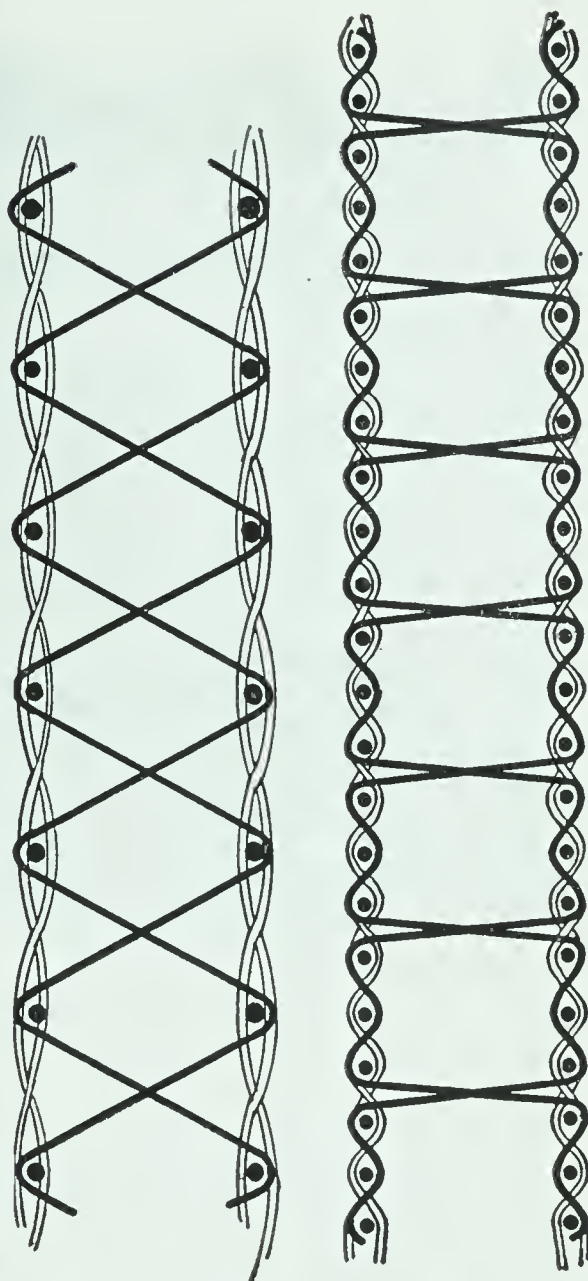
Pile warp over a wire. This method of construction is used in the manufacture of Wilton, Tapestry, and Velvet rugs. In this method the ground warp and the pile warp operate independently. The pile warp is raised from the ground cloth

in a separate shed, a wire is inserted, and the pile yarn is returned to the foundation cloth to be held down by the interlacing of the filling yarn. At least three filling yarns should be interlaced with the warp pile in the formation of each loop.

If the loop which results from the pile yarn being passed over the wire is to remain uncut, plain wires are used which, when removed, leave the loop intact. If a cut pile is desired, wires are used with knives on the end. As the wire is removed, the knife cuts its way through the loops, leaving a pile of cut ends on the surface. (See page 42, top.)

Terry pile fabrics. Terry pile fabrics are constructed with uncut loops of warp yarns on both surfaces of the cloth. This is the one type of weaving in which each pick is not beaten back as inserted. In its construction the ground warp is held taut in the loom, but the pile warp is weighted less and is so arranged that when a group of picks is beaten up against the cloth, the pile warp slides along the ground warp and forms loops on both sides of the fabric. (See page 42, bottom.) Turkish toweling is a familiar fabric of this type.

Spot, swivel, and lappet. Spot, swivel, and lappet are a group of weaves quite similar in that in each an extra yarn or yarns are introduced in such a manner as to create a design on the surface of the cloth, but the three weaves differ markedly in



Drawing illustrating pile yarn bound once (left) and three times (right) in the construction of velvet by double-weaving method.

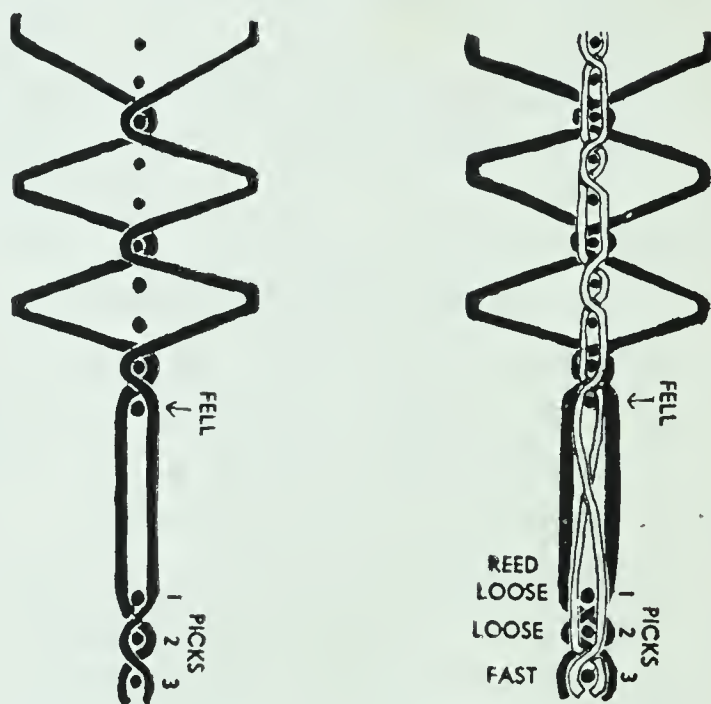


From Posselt's *Technology of Textile Design*, published by McGraw-Hill Book Co., Inc.

Diagram of method of constructing warp pile over a wire.

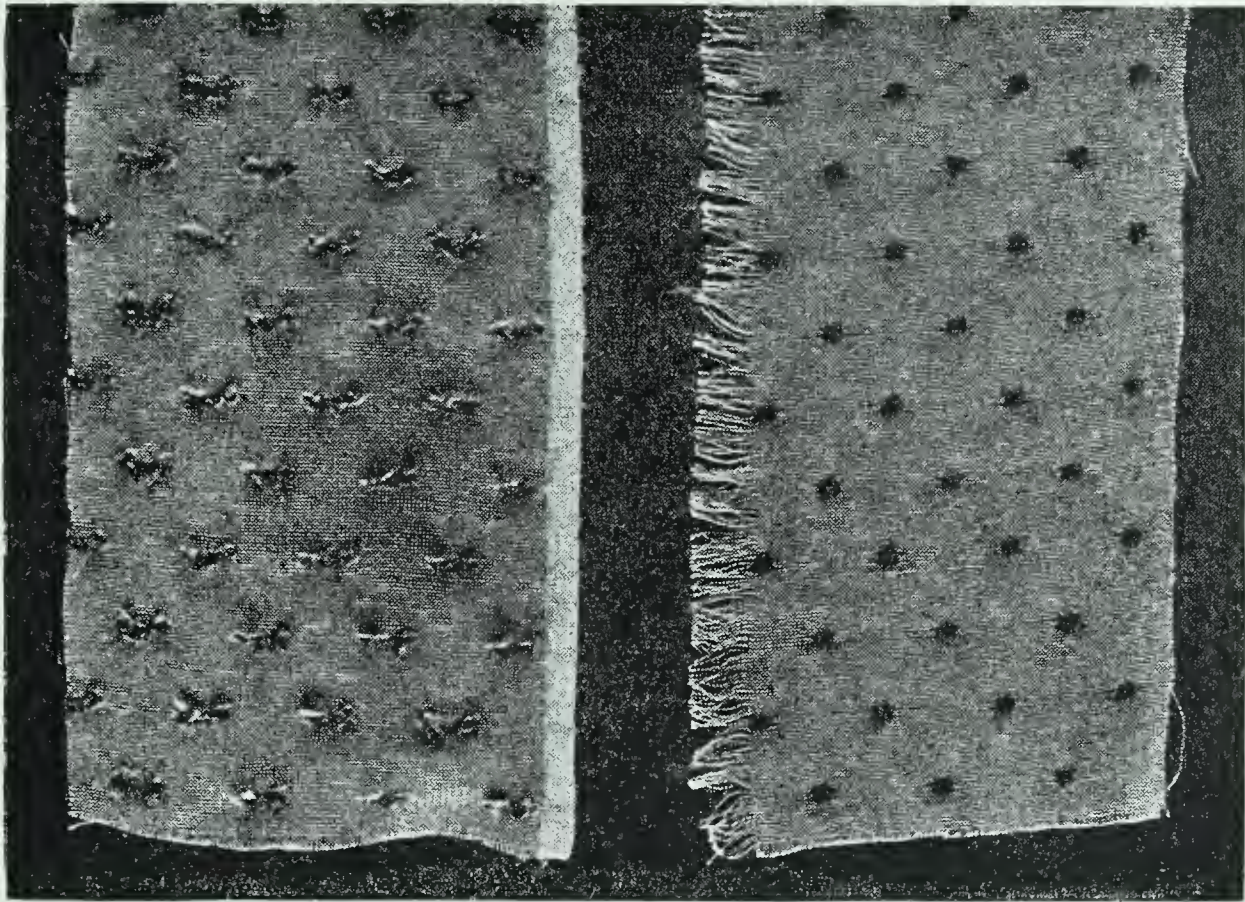
the manner in which this is accomplished. *Spot weaving.* The simplest form employs an extra set of filling or warp yarns, differing in weight and often in color from those used in the body of the fabric, to produce the design. (See page 43.) These yarns are thrown into the figure of the design on the face of the cloth and are carried from selvage to selvage across the back in long floats between figures, or in the case of warp yarns, they run the entire length of the cloth. The same yarns float on the back of the cloth as appear in the design on its surface. These floats between figures may or may not be cut, depending on the thickness of the fabric and its use. When these floats are cut off there are two cut ends for every yarn in the design.

The floats between the designs are removed during the finishing operations. The term clip-spot originated from the hand clipping of these floating yarns. The floating filling yarns are removed with little difficulty by a cloth-shearing machine. The movement of the cloth warp-wise, together with suction, lifts these yarns so they can be cut with the shearing knives into two hanging yarns. The air suction then pulls these loose ends away from the cloth and they are removed by the shearing knives.



From "The Weaving of Terry Fabrics," by Tufter, *Textile Recorder*, Vol. 47 (1930), p. 29

Diagrams illustrating the construction of terry-pile fabric. Left, manner in which pile yarns are interlaced with filling; right, manner in which the ground warp is interlaced.

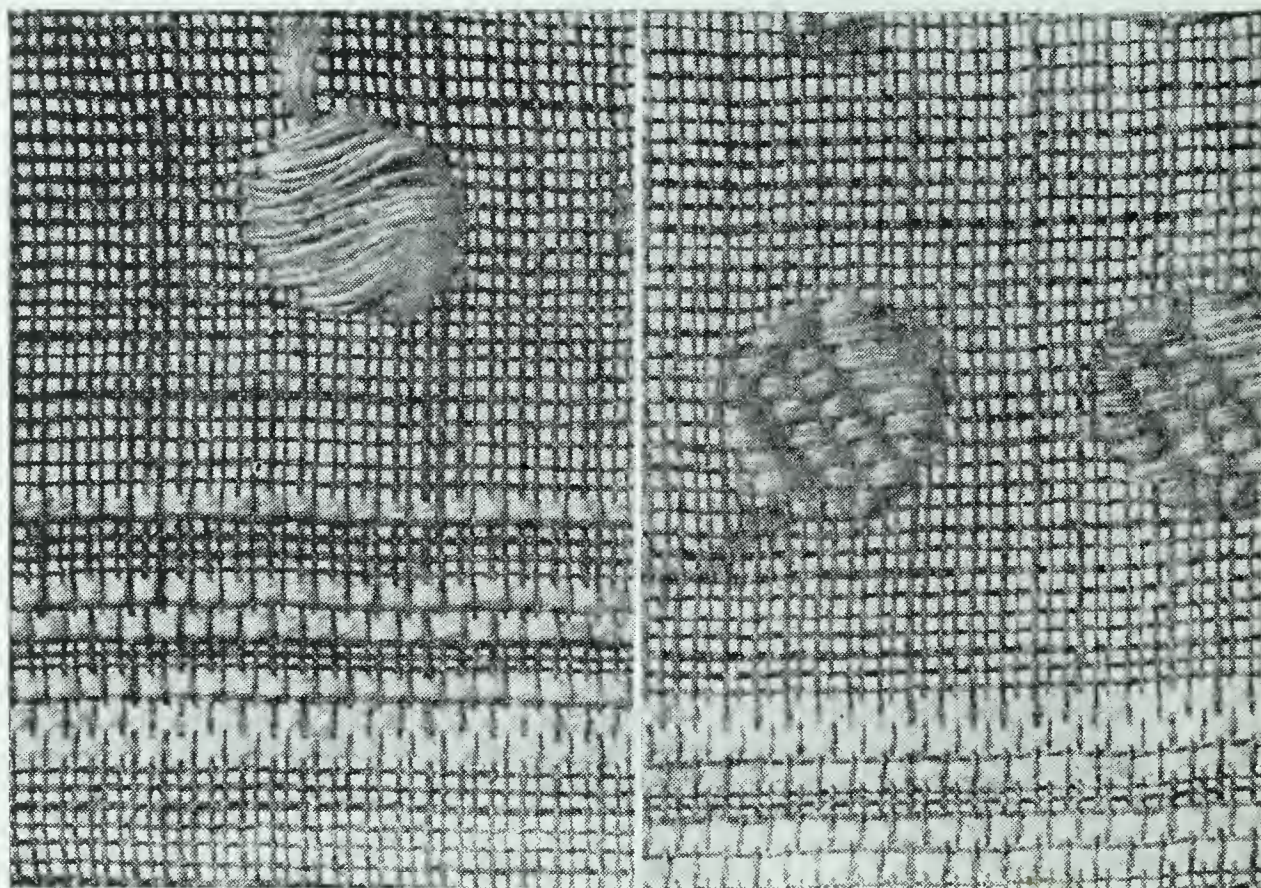
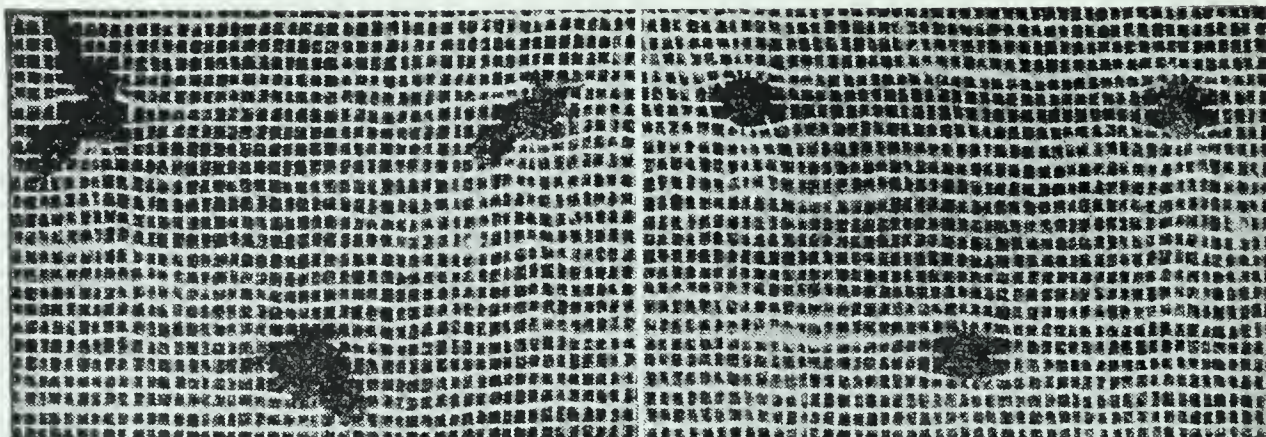


Fabric, showing clipped spot. Left, back of the fabric; right, face of the fabric. Note the cut ends of the designing yarn on the back of the cloth.

Warp floats are difficult to remove because they usually lie close to the cloth and the warpwise movement of the cloth tends to make them cling more closely rather than lifting them as is the case with the floating filling yarns. A special type of apparatus is required to lift and cut these floating warp yarns.

The spot type of design is many times found to be unsatisfactory, as the durability of the design is dependent only on the compactness of the ground yarns which hold the heavy designing yarn in place.

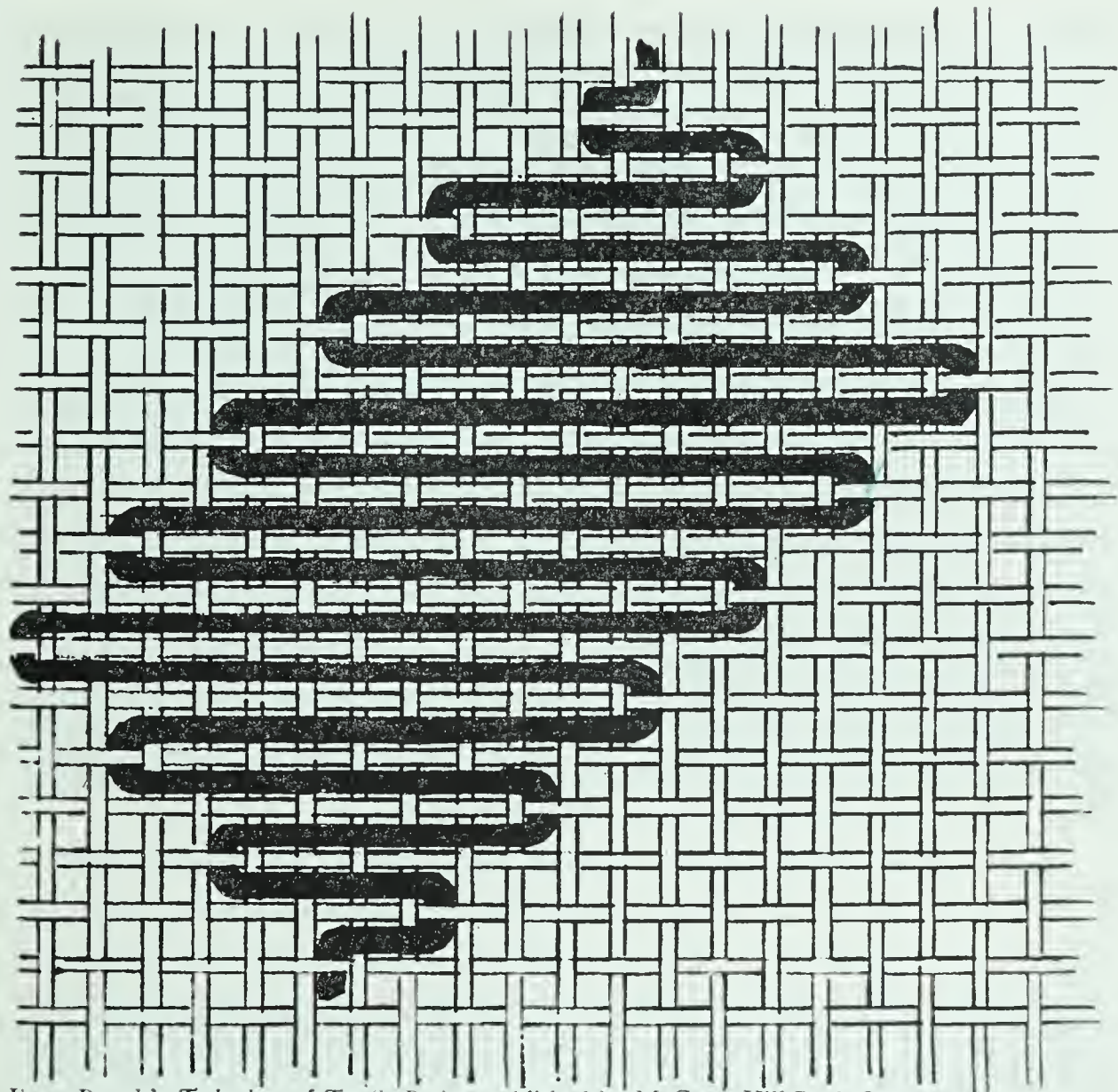
Swivel. Swivel is another method of producing design with an extra filling yarn. After the ground filling carried in the common shuttle has been interwoven, a separate shed is opened for the introduction of the small swivel shuttles carrying the extra filling to form the design. In using a fly shuttle in common weaving, one filling must be used in all the figures in a row; whereas the swivel permits the weaving of different



Magnifications of two fabrics, showing use of swivel method of producing the design. Note the amount of yarn showing on the wrong side. (Illustrations at left show wrong side.)

colors in the same row, because each figure is formed by its own shuttle.

In fabrics having small designs, the swivel is used to save material and to give such figures a more prominent appearance than can otherwise be obtained. (See page 44.) In the swivel method the yarn is securely fastened as each figure is finished, and there is no danger that the design will pull out.



From Posselt's *Technology of Textile Design*, published by McGraw-Hill Book Co., Inc.

Drawing of lappet weaving. The lappet yarn is held down only at the edges of the design as the filling yarn passes over it.



Small design constructed by lappet weaving. Note only two cut ends of designing yarn.

Fabrics with swivel-woven designs are usually an imported material and are often designated as tied-knot swisses. They may be recognized by the fact that the designing yarn is usually the same on both sides of the fabric. It appears to go around a group of warp yarns. In the construction, of course, the group of warp yarns were lifted and lowered for the passage of the shuttle. Both ends are covered and hence securely fastened, but they are not tied.

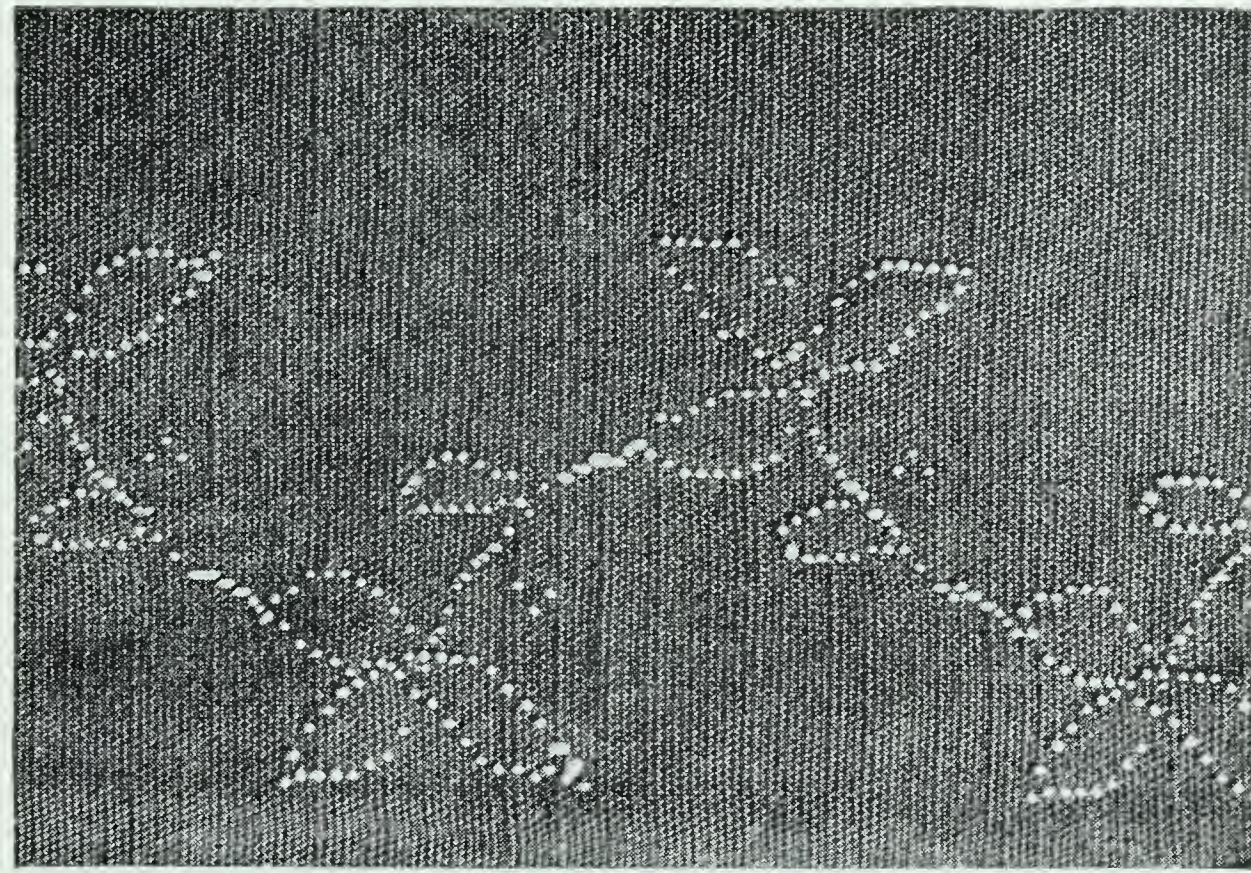
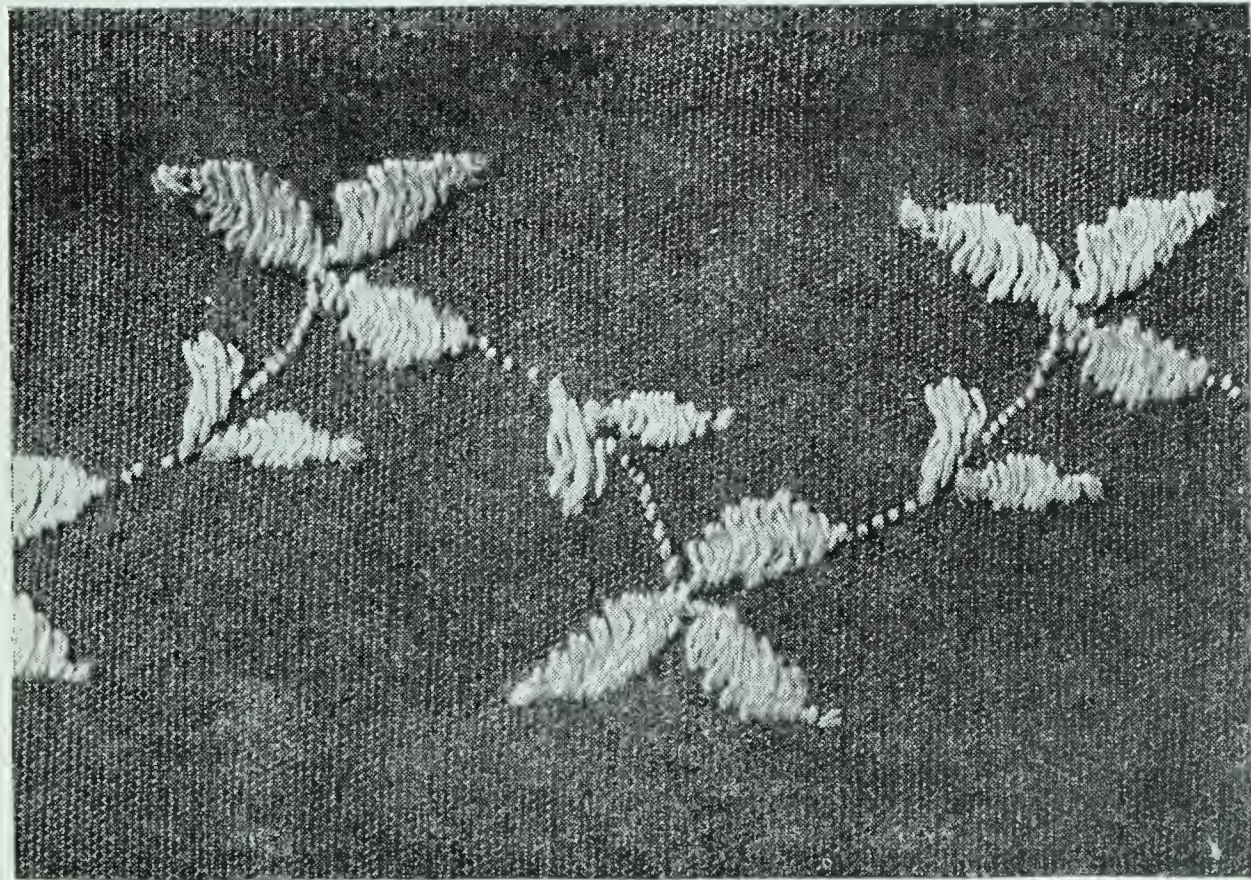
Lappet weaving. In this system of weaving, special figuring or "whip" yarns are introduced as extra warp. These warp yarns are carried in a horizontal direction on the face of the fabric and are bound by a filling yarn only at the extreme edges of the design. As the foundation of the cloth must be firm to withstand the sideward pull of the figuring yarn, plain or gauze weave is usually employed.

A special type of apparatus is required to carry the warp figuring yarn across the fabric. This consists of a frame of needles which is placed in front of the reed.

In the production of the design the needles are first lowered to the bottom of the shed, thus placing the designing yarn in this lowered position. The shuttle is then passed through the shed over the lappet ends and the needles are lifted while the reed presses the filling into place. By means of a lateral shift of the needle frame, the lappet ends are carried above and across a few ground warp yarns and are in position for the next interlacing with the filling yarn. There is practically no waste of yarn between figures. If the design is a small, separate figure, the yarn between designs is clipped off. (See page 45.) Fabrics employing small, separate figures constructed by lappet weaving are not always easy to obtain, but this method of inserting a designing yarn is employed in many types of fabrics. This method of designing is also employed in some knitted fabrics.

Tapestry. As the term is used today, tapestry includes many types of fabrics. However, according to one encyclopedia,

[Tapestries] are decorative pictures or designs in tissue which are made by interlacing variously colored woof threads with un-



Lappet-woven fabric. Left, face of fabric; right, back of fabric.



A hand-woven Philippine cloth illustrating true tapestry weaving.

dyed warp threads after the latter have been extended either vertically or horizontally upon a loom. This interweaving is done with an implement called a "broche," in France, which is neither a shuttle nor a bobbin, but partakes of the character of both and



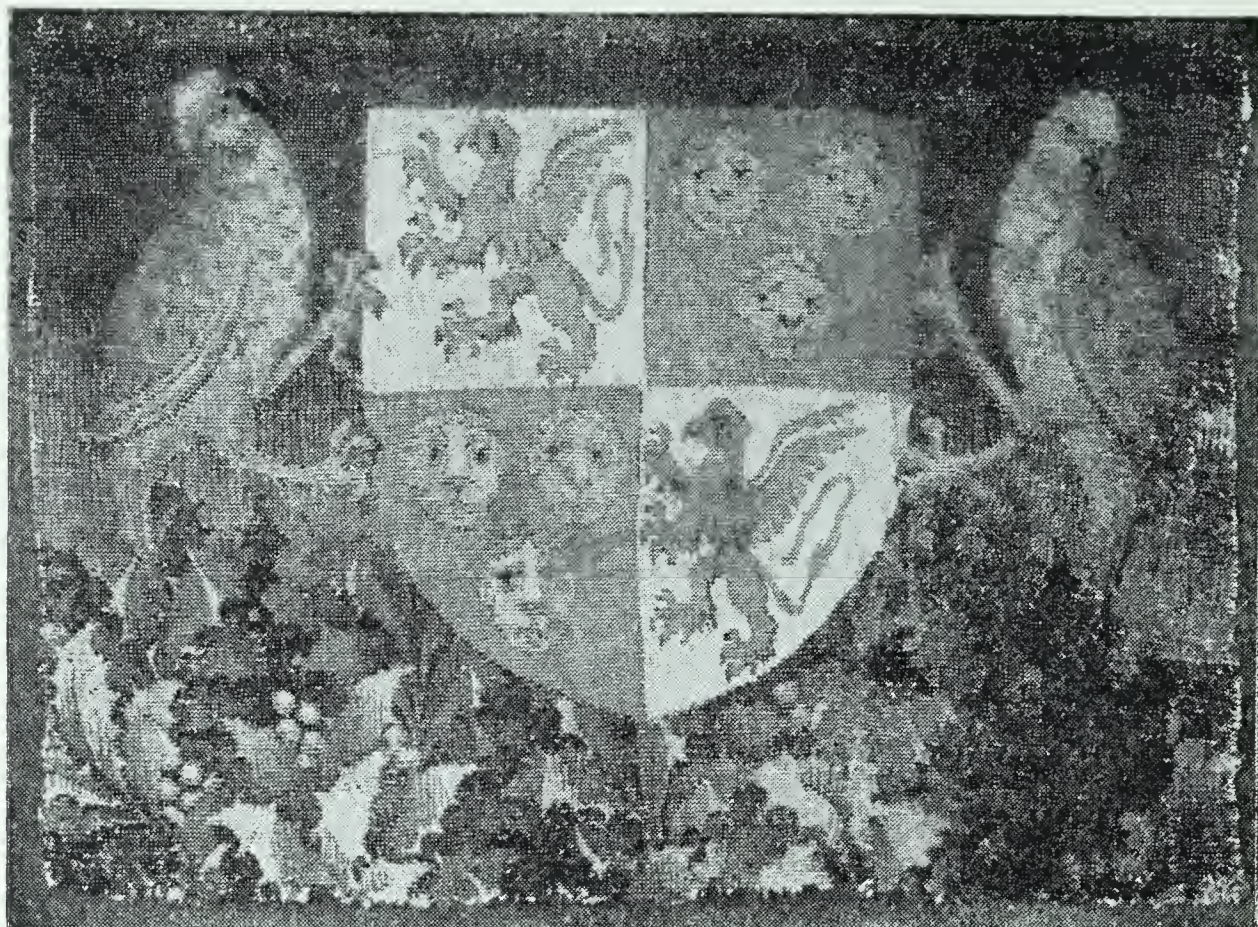
Courtesy Museum of Fine Arts, Boston

French tapestry, "Le Déjeuner," designed by François Boucher Beauvais, 1756. Such tapestries are highly valued works of art.

for which there is no equivalent word in English. The picture represented is developed upon the warp by the different colors of the woof threads. Needles are never used in weaving tapestries.¹

In tapestry weaving there is no yarn carried completely across the width of the material. (See page 48.) The designing yarns are carried back and forth across certain warp yarns by means of a broche and are knotted to hold them in place.

¹ *Encyclopedia Americana*, Vol. 16.



Courtesy Museum of Fine Arts, Boston

Flemish tapestry, coat of arms made for Cardinal Ferry de Cluny, 1480–1483. Details of weaving are readily discernible.

In all weaving so far described, the filling yarns are carried by means of a shuttle from selvage to selvage. Tapestry cannot be rightfully called embroidery because there is no completed fabric on which the pattern is made.

In the construction of tapestries the warp yarns are held in either a horizontal or vertical position and the artist works from the back, following a colored drawing the full size of the design. However, the artist interprets the colored drawing, rather than following it accurately; thus his individual artistic ability is shown in his work. (See illustration above.)

The operator works on the wrong side of the tapestry and cannot criticize his work as it develops. In certain high-art tapestries the weaver can weave only about a yard square in a year. In the Gobelins, today, this yard square costs about \$880.

Today, according to Watson,¹

¹ William Watson, *Advanced Textile Design*, p. 186. Longmans, Green and Co., 1925.

Almost every class of fabric structure is used for tapestry and upholstery purposes, ranging from cloths composed of one warp and one weft to those in which two or more series of threads are introduced in one or both directions.

Authorities do not always agree on the difference between brocades and tapestries. High-quality woven fabrics known as tapestries are constructed with double weaving, and metal threads are often used to bring out the design.

Suggestions for the Laboratory

Compare the service qualities of various fabrics of the three fundamental weaves. How many of the fibers are used in the construction of fabrics by these weaves?

Compare fabrics constructed by figure weaving, gauze and imitation gauze weaving. In what type of fabrics are these constructions used?

How many fabrics now available are constructed by spot, swivel, or lappet weaving? Can you distinguish between the "V" and "W" interlacings in pile fabrics? In the double cloths available was the purpose of the interlacing that of design or thickness?

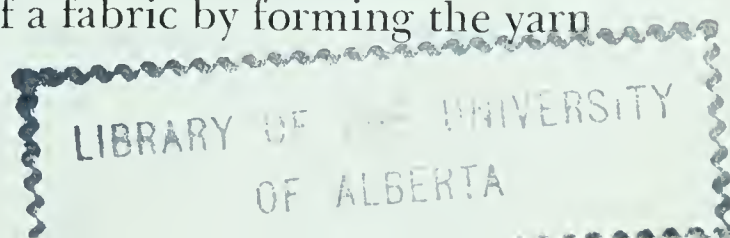
In the fabrics studied what type of weaving is most often used in clothing fabrics and in household fabrics?

Identify 15 standard plain weave fabrics, 10 of pile weave, 5 of satin weave, and 5 of figure weave.

PROBLEM 4. HOW IS KNITTING DONE?

Knitting. Knitting is a method of fabric construction of comparatively recent development, but it has improved so rapidly that it is now second in importance only to weaving. We are unable to place it chronologically as a contribution of any one period, but it seems to have been used not earlier than the fifteenth century. It appears as the result of a demand for cloth possessing sufficient elasticity to conform to the lines of the figure. Originally this was handmade and used only for hosiery and underwear, but in recent years it has been popular for outerwear—coats, suits, and dresses.

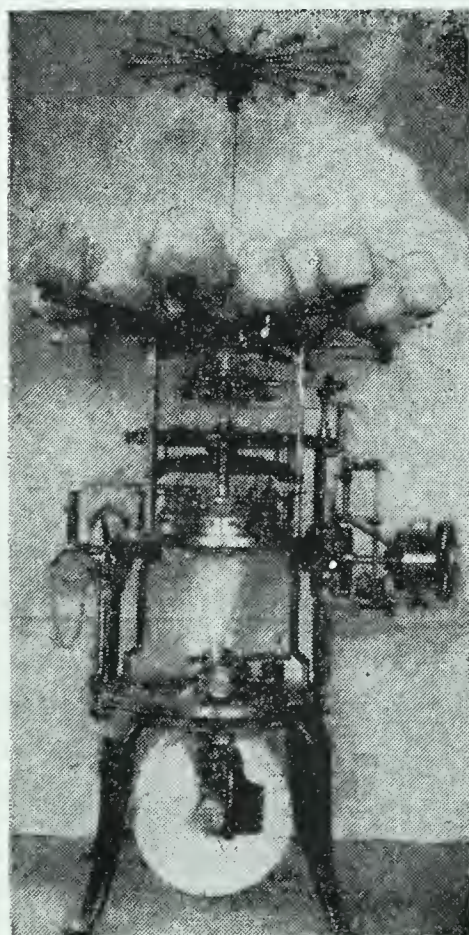
Knitting is the construction of a fabric by forming the yarn





Courtesy *Textile World*

An efficient position of the hands for knitting.



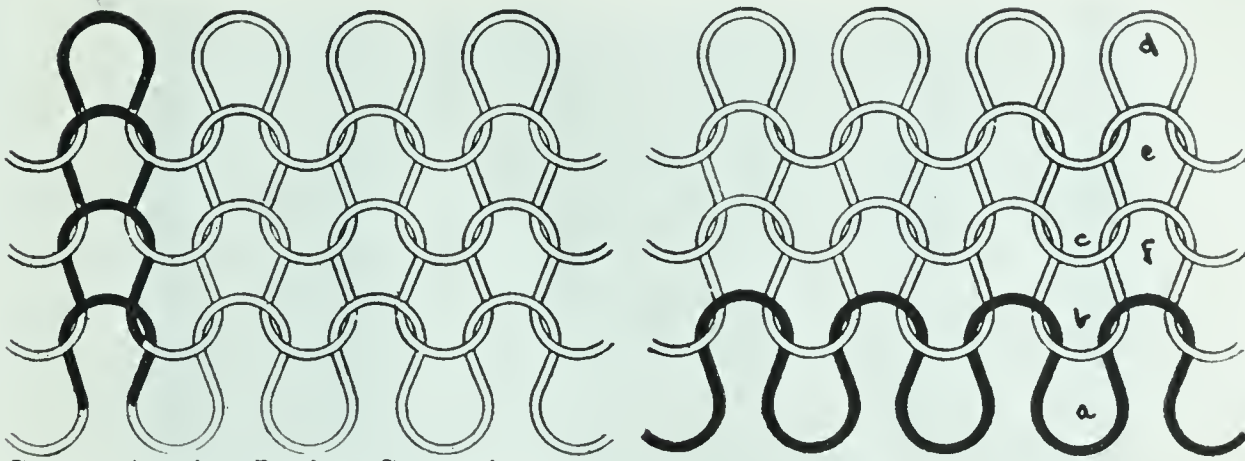
Courtesy Wildman Manufacturing Co.

One type of modern knitting machine.

into loops which hang one upon the other. This fabric may be constructed from a single yarn that runs across the fabric or from a group of yarns that run lengthwise. The work may be done by machinery or by hand.

The lengthwise rows of loops are known as wales, and the rows running crosswise are called courses. (See page 53, top.) The number of wales and courses in a square inch of knitted goods determines its density. The gauge of hosiery or other knitted fabrics is determined by the number of loops in one and one-half inches and is used as a means of determining fineness or closeness of the structure.

There are two types of knitted materials, *filling knit* and *warp knit*.

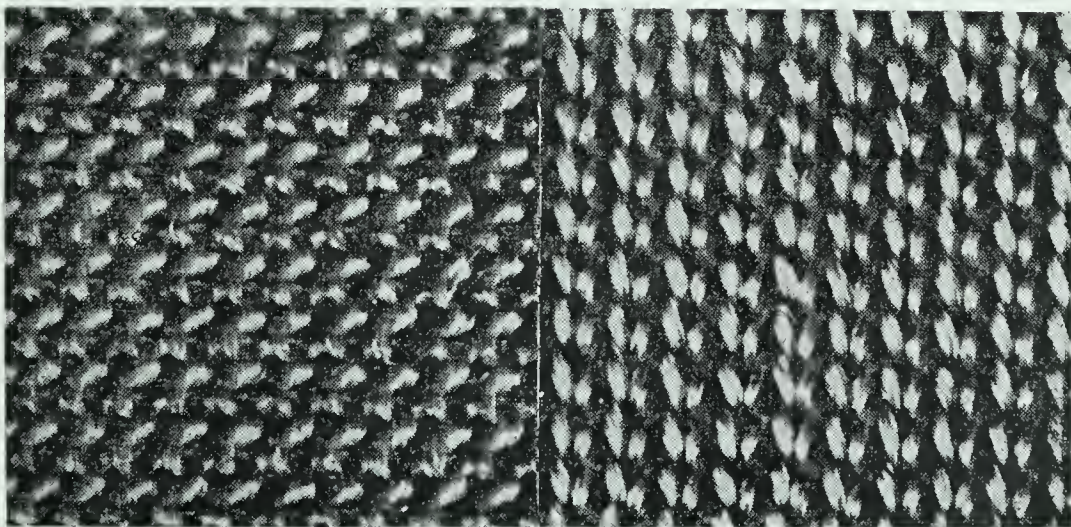


Courtesy American Bemberg Corporation

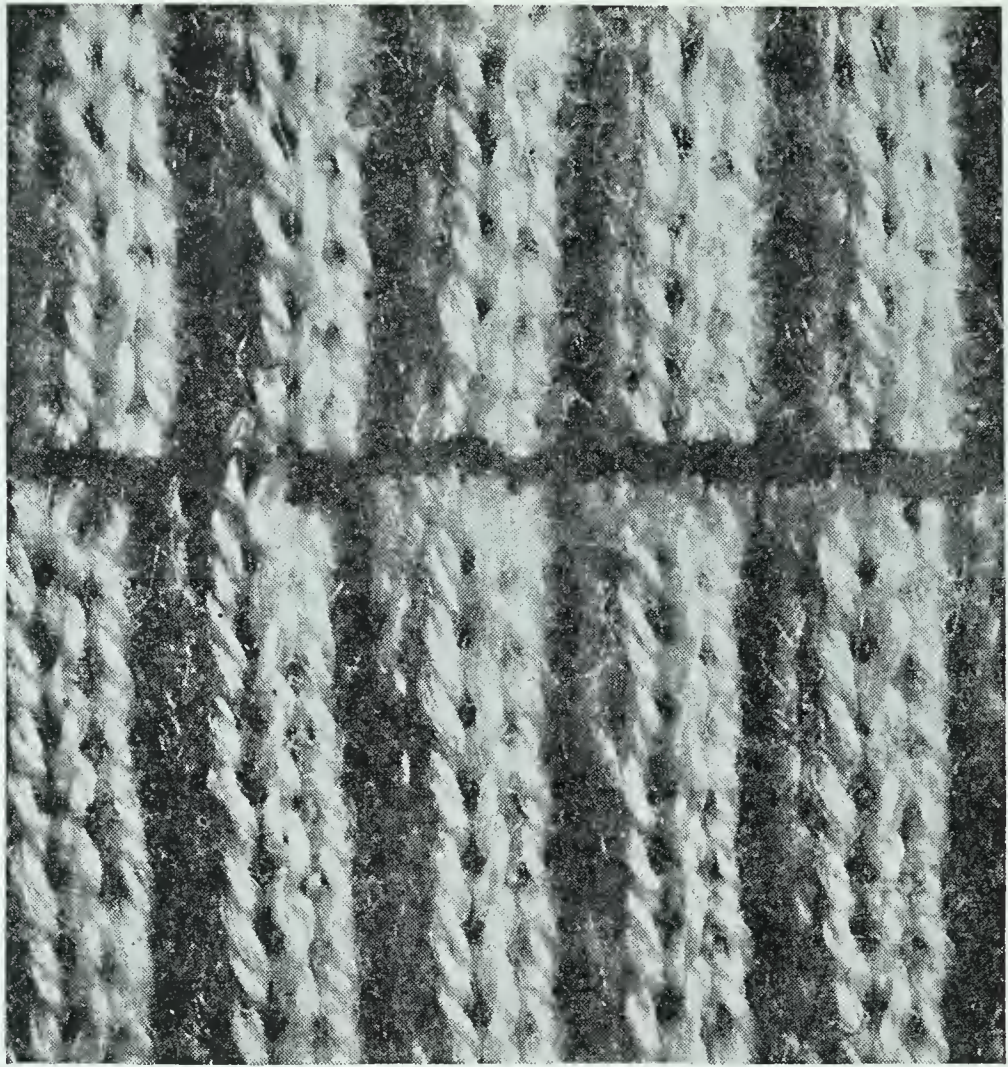
Left, plain weft knitting, illustrating courses; right, illustrating wales.

These two types, named from the direction in which the yarn runs, differ in their method of construction, character, and properties.

Filling knit fabrics constitute much the greater portion of knit goods. They are simple in construction and are easily made by hand. Machine-made filling knit materials are found in all types of garments and are competing with woven and warp knit fabrics once considered the only materials suitable for outerwear. In filling knit fabrics a single yarn travels in loops across the fabric, each loop being built consecutively. The work is done on one or more needles, depending upon the form of the garment or fabric. The stitches differ only in the manner in which the yarn is thrown and in how the needle is placed in the stitch.



Plain knit fabric. Right, right side; left, wrong side.

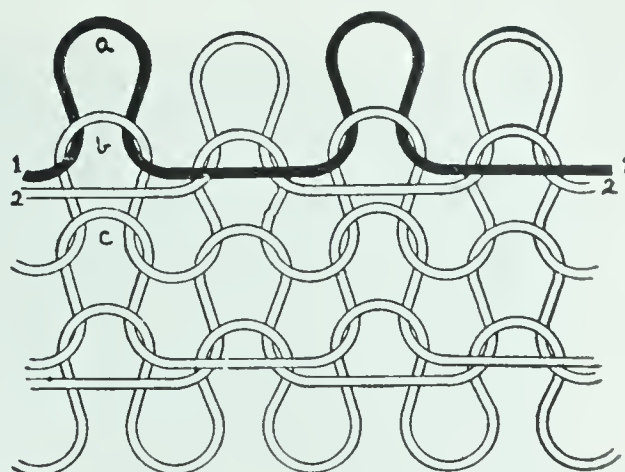


Rib-knit fabric: right side and wrong side. Note similarity.

The *plain* stitch is the simplest stitch, and when constructed by going around and around the garment, usually on circular needles, the resulting material is comparatively smooth on the wrong side and shows a slight ribbed effect on the right side. The *purl* stitch is exactly the reverse of the plain stitch, having the smooth effect on the front and the ribbed effect on the back. A fabric alike in appearance on both sides is made in flat material by knitting one row across, reversing the material, and knitting back, thus throwing first one side and then the other side of the stitch to the front.

Ribbed fabrics are constructed by grouping the plain and purl stitches in the desired manner. All types of fancy and novelty effects are produced from the combination of plain, purl, and ribbed stitches together with the knitting of two stitches as one, the slipping off of stitches unknitted, the addition of a stitch, or the dropping of a stitch as desired.

Filling knit fabrics are characterized by their elasticity and their tendency to run or form ladders. This last tendency is objectionable, but it is offset by their elasticity and ability to conform to the body. For this reason filling knit hosiery is more desirable than warp knit hosiery.



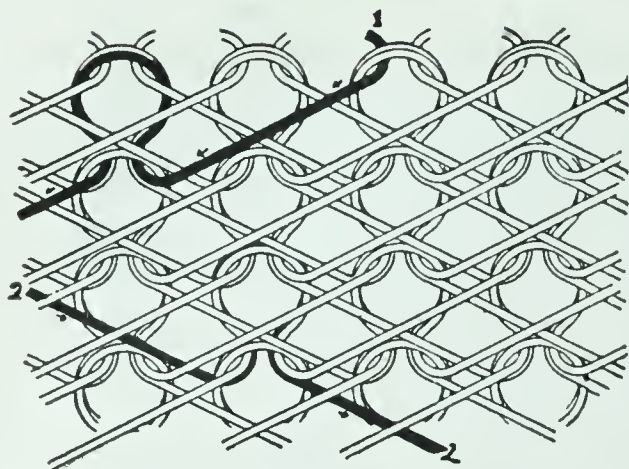
Courtesy American Bemberg Corporation

Run-resist filling knit.

Machinery has been produced at various times for the production of nonrun filling knit hosiery for which much is claimed. None of these types has as yet proved entirely satisfactory. One such method of interlacing is illustrated above. The lace hosiery more or less popular at various times usually resists runners. However, in order to secure the desired texture it is necessary to use finer yarn than is required to secure the same sheerness in filling knit hosiery. Hosiery so produced will be comparatively runproof but will not give as good service in the foot as ordinary filling knit hosiery of the same quality.

Warp knitting consists of the looping together of one or more series of warp yarns. These yarns are sometimes placed on a beam as for weaving. From the beam the yarns are brought forward in a parallel manner to the needles, of which there is one for every end of yarn. In order to construct a fabric from a series of warp yarns it is necessary for them to be interlooped with each other. To accomplish this the yarns are drawn through a series of guides or eyelets which are free to move back and forth and sidewise and thus present the individual yarns to the correct needle in a predetermined manner. The cloth is knit in a horizontal flat piece and is wound onto a roller.

In warp knitting the loops are interlocked in such a manner as either to resist or prevent running. This type of fabric was first produced for use as outerwear, but it has been adapted to the production of underwear. Warp knitting is a



Milanese fabric, showing diagonal manner in which the yarn is inter-looped. This is the distinguishing feature of this type of knitting.

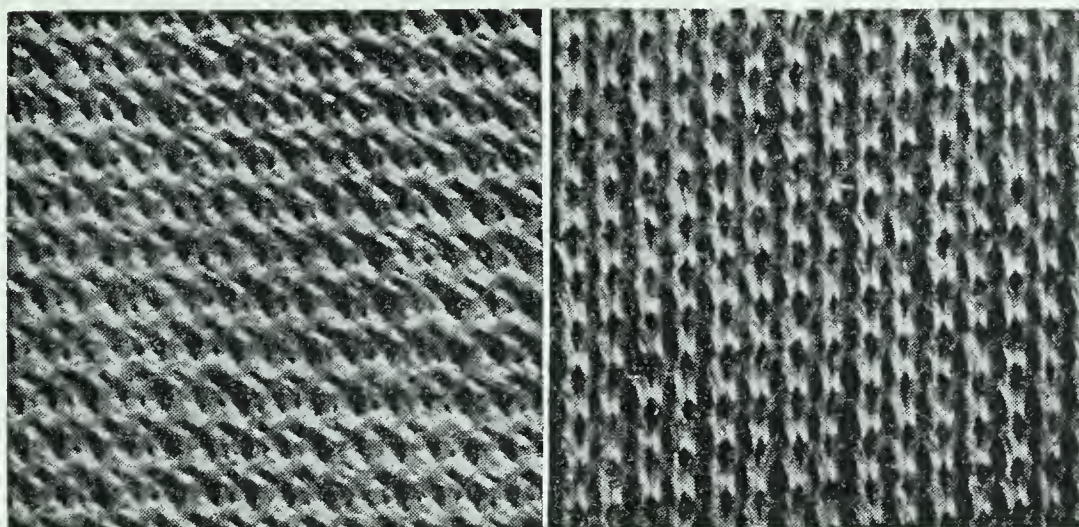
rapid process because a series of yarns is used and many loops are formed at the same time. It is possible to produce one million stitches per minute on this type of machine. The two main types of warp knitted fabrics are *Milanese* and *tricot*. In both these types the warp yarns are interlocked; however, differences in the methods of construction result in fabrics vary-

ing widely in general appearance, texture, and weight.

Milanese fabric has been termed the “queen” of knitted fabrics because of its fine texture, comparative elasticity, and resistance to runs. Milanese fabrics are constructed from two sets of warp yarns, one of which forms the face and the other the back of the fabric. These yarns are carried from side to side of the fabric in the formation of the stitch. As the loop is made, the face yarns are moved one stitch to the right and the back yarns are moved one stitch to the left until the extreme side is reached; there the back and face yarns exchange places and travel again in the opposite direction. Two stitches, one each of the back yarn and the face yarn, are taken on the same needle and are crossed in the formation of the loop. The resulting diagonal movement of the yarns in Milanese-knit fabrics can be seen easily by holding the fabric to the light or by drawing a yarn through the fabric. This serves as a means of identification of this type of construction. (See picture above.)

Milanese fabrics have a high breaking strength as well as a resistance to runs or ladders, and are elastic to a limited degree in both width and length. New and improved types of machines permit a greatly increased production, thereby reducing the cost of the fabric.

The first fabrics produced on Milanese machines were used for gloves. Today, both gloves and underwear fabrics, and, to



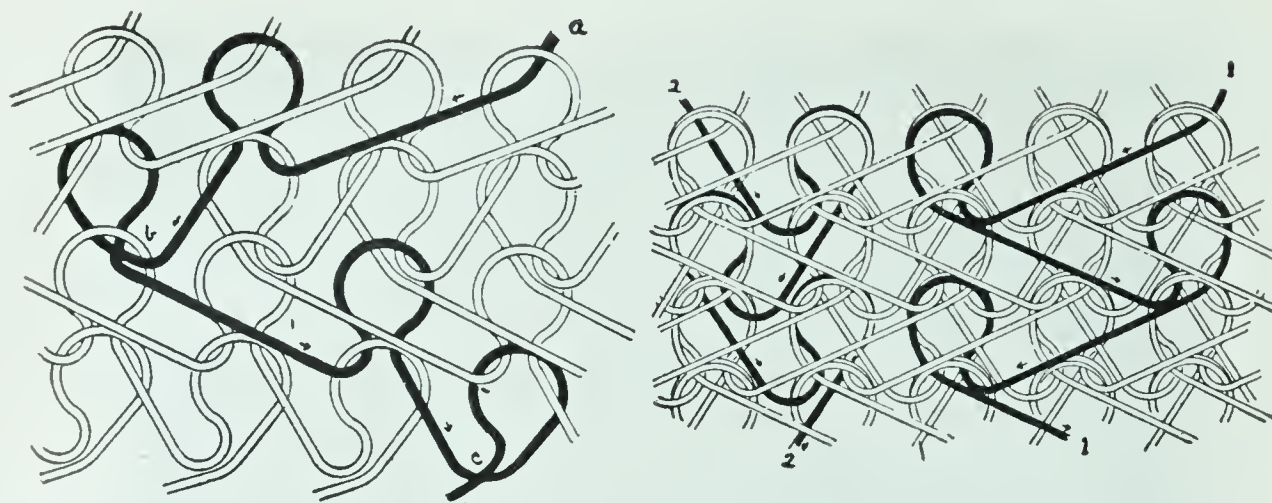
Milanese cloth, a warp-knit fabric. Left, wrong side; right, right side.

a limited degree, dress fabrics, are produced on the Milanese machines. There are only two types of stitches that can be used, and this limits the design that can be produced to that of stripes or plaids. In 1943 there were 322 Milanese machines reported in use in the United States.

Tricot fabrics are comparatively heavy in texture, appearing as a double cloth. On the face of the fabric rows are seen running vertically, whereas on the back the rows appear to run across from side to side.

Tricot fabrics fall into the following classifications: single-bar, two-bar, three-bar, and cut-presser. These fabrics differ in the number of warp and guide bars employed. Single-bar uses usually one warp and one guide bar, double-bar uses two of each, and three-bar uses three of each. Many variations of these arrangements may be employed. The cut-presser attachment is so arranged as to operate only at intervals in order to produce a design. There is no limit to the types of fabric and designs which can be produced on these machines. These fabrics range from the finest nets to the heaviest overcoatings.

Single-bar tricot fabrics are run-resistant but not run-proof. The greatest use of these fabrics is in underwear manufacture. Two-bar tricot fabrics are definitely run-proof, which results in a trend toward a greater production of this type. In their construction two warp yarns are interlooped through the



Courtesy American Bemberg Corporation

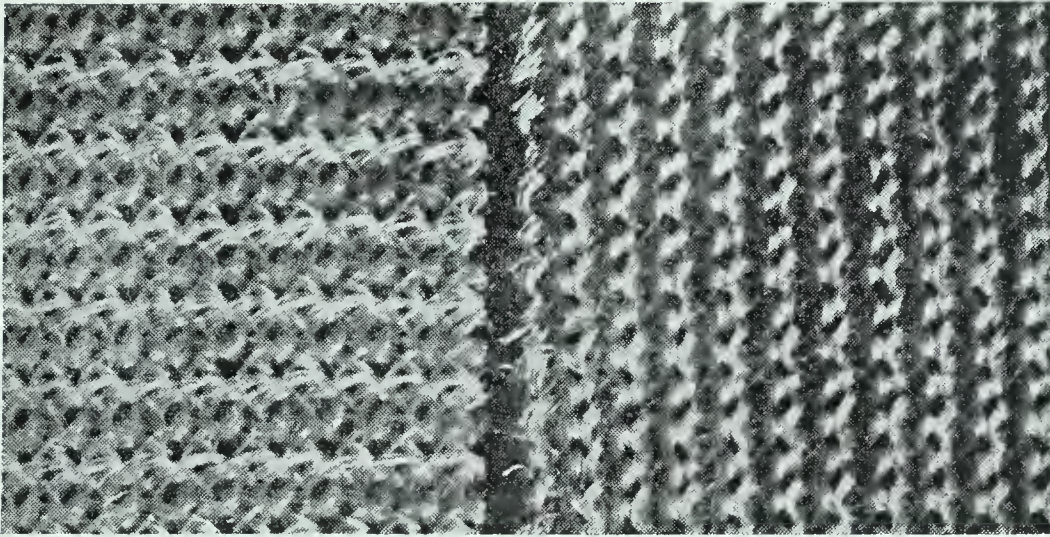
Left, single-warp (one-bar) tricot, and right, double-warp (two-bar) tricot, show the ravelproof character of the knitting.

movement of the yarns over and under the needles. These fabrics can be made either plain or fancy with or without open-work designs.

Two-bar tricot fabrics are popular for dresses and other outerwear. The recent improvement in construction of this type of fabrics has caused them to be considered as staples. By combining different types of filament and spun yarns, an almost unlimited number of designs can be obtained.

The flexibility of the tricot machine was illustrated in the production of a wide variety of fabrics for the use of the armed forces. A fine type of insect netting fabric and also a heavy camouflage netting were produced for the government on tricot machines. Some nets of this construction are available for curtain material.

The cut-presser machines permit novel and raised effects to be produced in one-bar, two-bar, and three-bar fabrics. Because the cut-presser attachment is in operation only when the pattern is being produced, it slows down the process. The speed of production depends upon the design desired. In 1943 there were in operation in the United States 638 slow-speed tricots, 608 high-speed tricots, and 14 cut-pressers. The slow-speed machines produce from 160 to 225 courses per minute and the high-speed machines produce from 250 to 450 courses per minute.



Tricot cloth, a warp-knit fabric. Left, wrong side; right, right side.

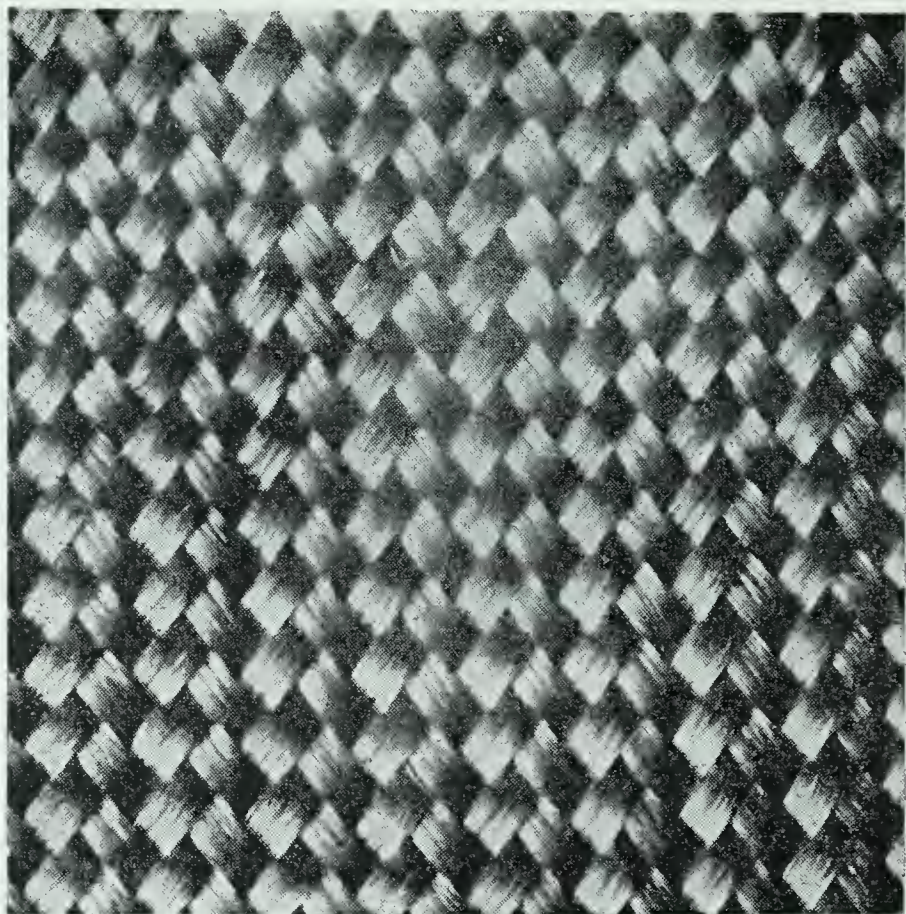
The heavy, firm effect of woven fabrics is simulated in knit goods by the use of extra stuffing or plaiting yarns. These may be added in the form of a design or simply for firmness. One type of these fabrics is sometimes spoken of as knitted tweeds. Special finishing that practically covers up the stitch makes the identification of some knitted goods, as such, difficult.

Suggestion for the Laboratory

Select and compare fabrics illustrating the different kinds of warp and weft knitting. Select fabrics suitable for outerwear and underwear.

PROBLEM 5. HOW ARE BRAIDS AND NETS CONSTRUCTED?

Braiding. Braiding is a method of fabric construction which has only a limited use because of the characteristics of the product. In braiding, yarns from a single source are crossed diagonally and lengthwise. This form of interlacing is used not only with every type of textile fiber but also with a wide range of materials not commonly recognized as textiles, such as straw, cornhusks, and leather. In fact, any flexible material that can be made into a continuous length can be used in braiding. Braided rugs and hats and braided trimmings are illustrations of this early form of fabric construction.

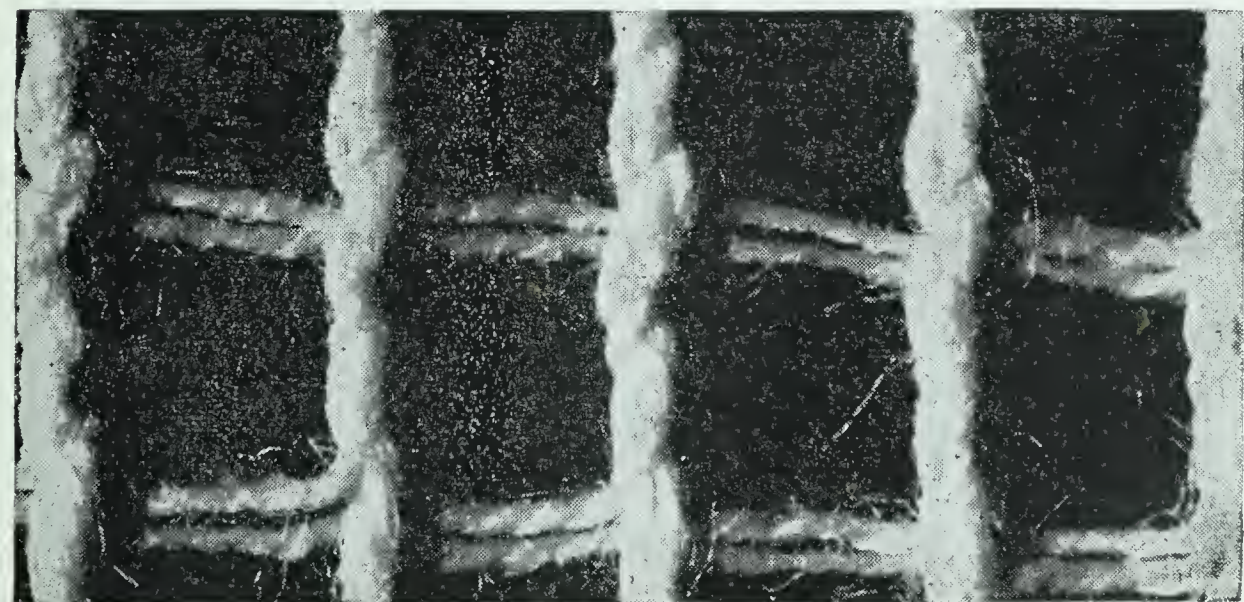
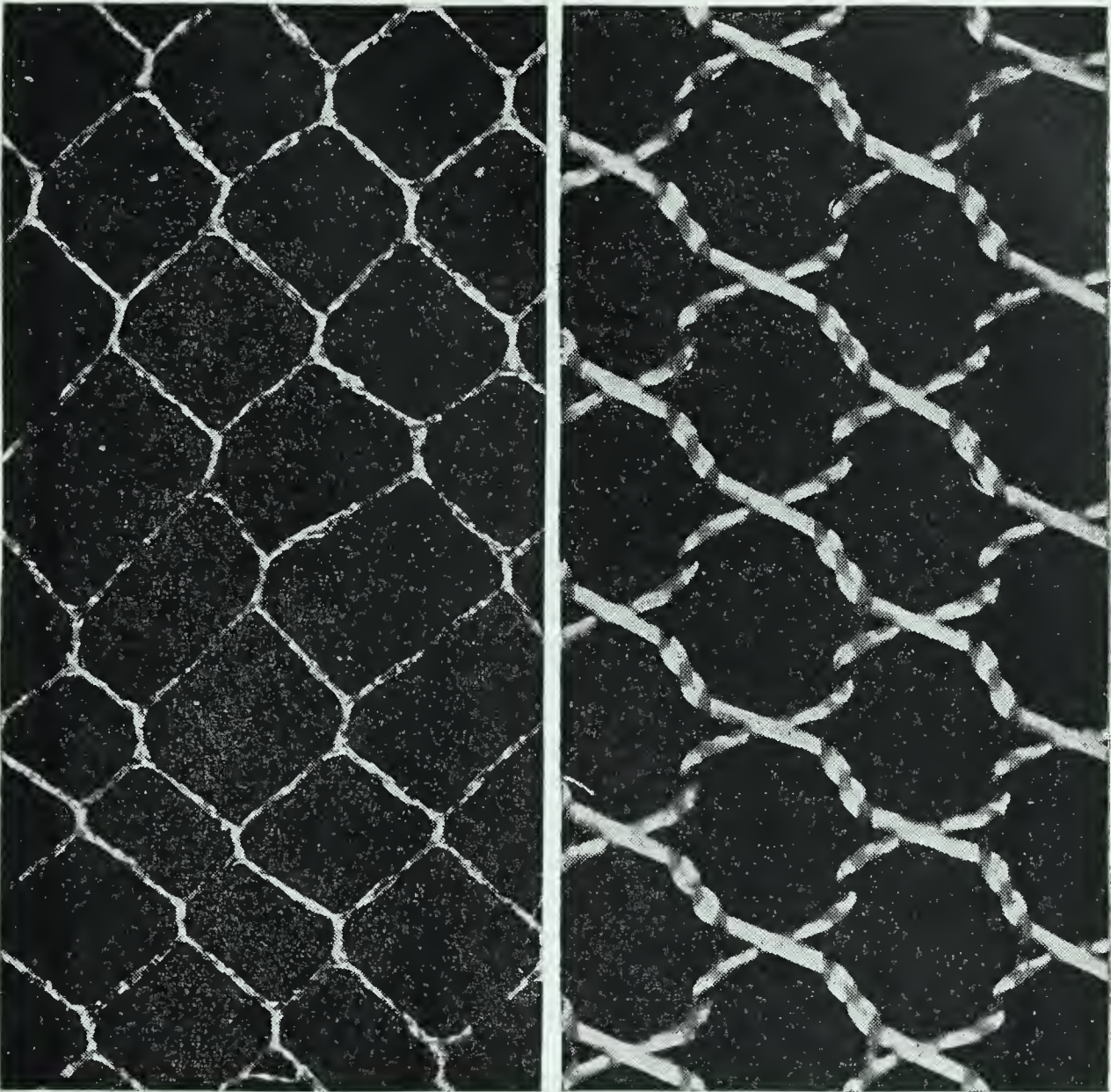


Braided fabric.

Braids once made by hand are now produced chiefly by power machines, a single model being adjustable for several widths and types of braid. The use of these machines has replaced the housewife's handicraft by production on a large scale. In some countries, however, the braiding of hats and mats remains a hand process.

Nets—open-mesh fabrics. An outstanding characteristic of nets is the open mesh or the large interstices between the interlacing yarns of which the fabric is made.

Originally net was an open-mesh fabric in which the interlacing threads were knotted at every point where they crossed each other. When done by hand, this knotting makes a regular mesh of three to six equal sides. After many unsuccessful attempts to imitate the form, in 1809 a machine was perfected which was able to manipulate the thread successfully in three directions and thus produce a fabric with the three to six equal-sided mesh. It so nearly resembles the hand-made net that only an expert is able to distinguish the difference.



Three types of braided net. Top left, fine silk; top right, rayon; and bottom, cotton curtain material.



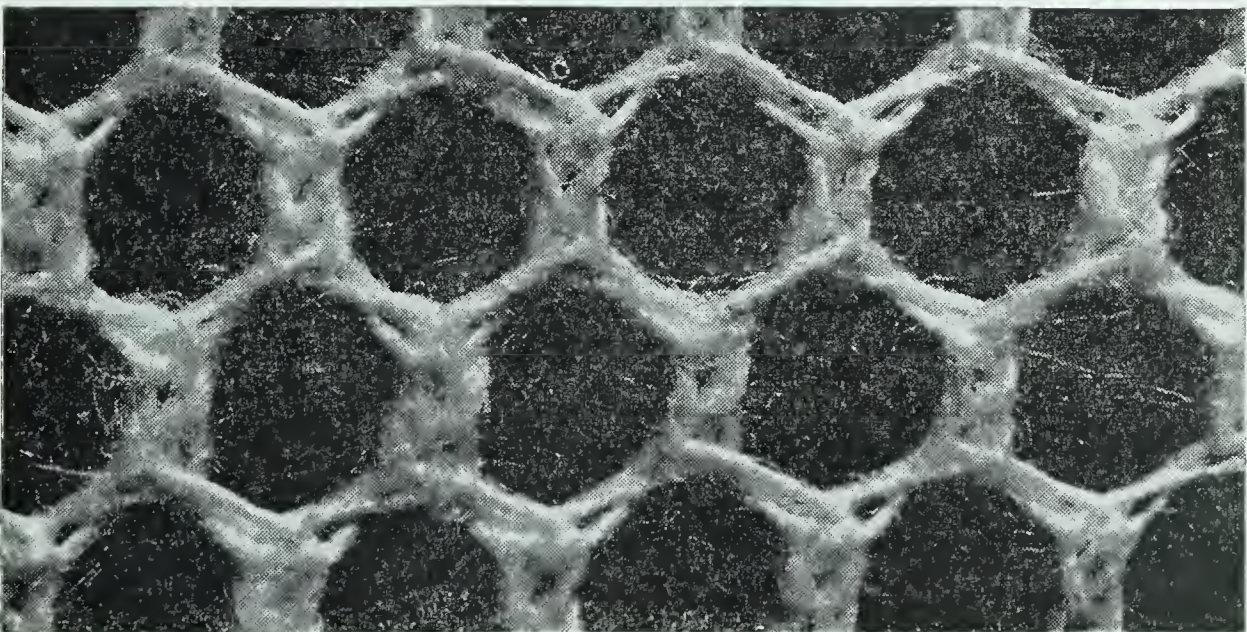
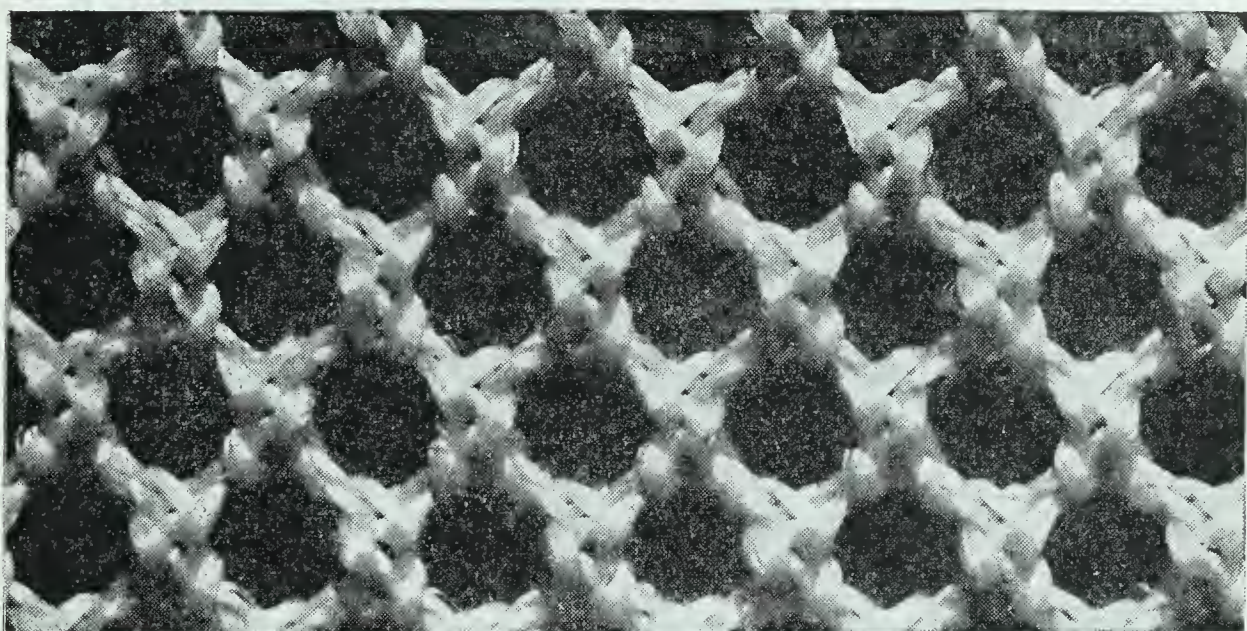
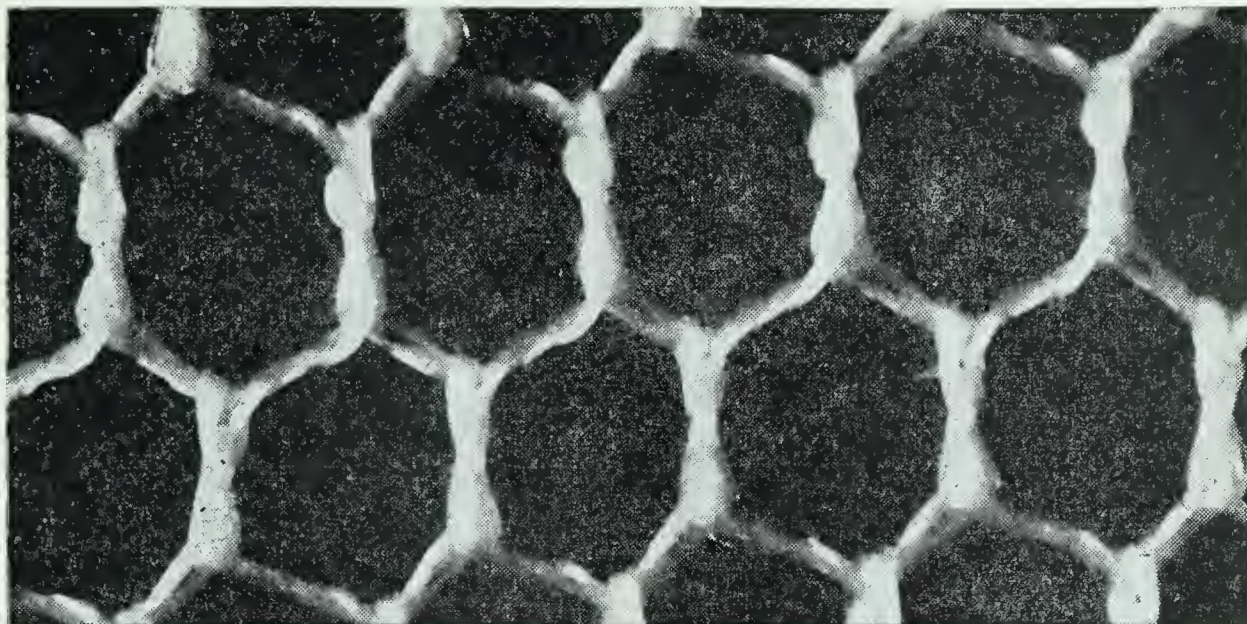
Bobbinet, an example of machine-made net.

Fabrics similar to this are now being constructed on tricot knitting machines. (See the illustrations on page 63.)

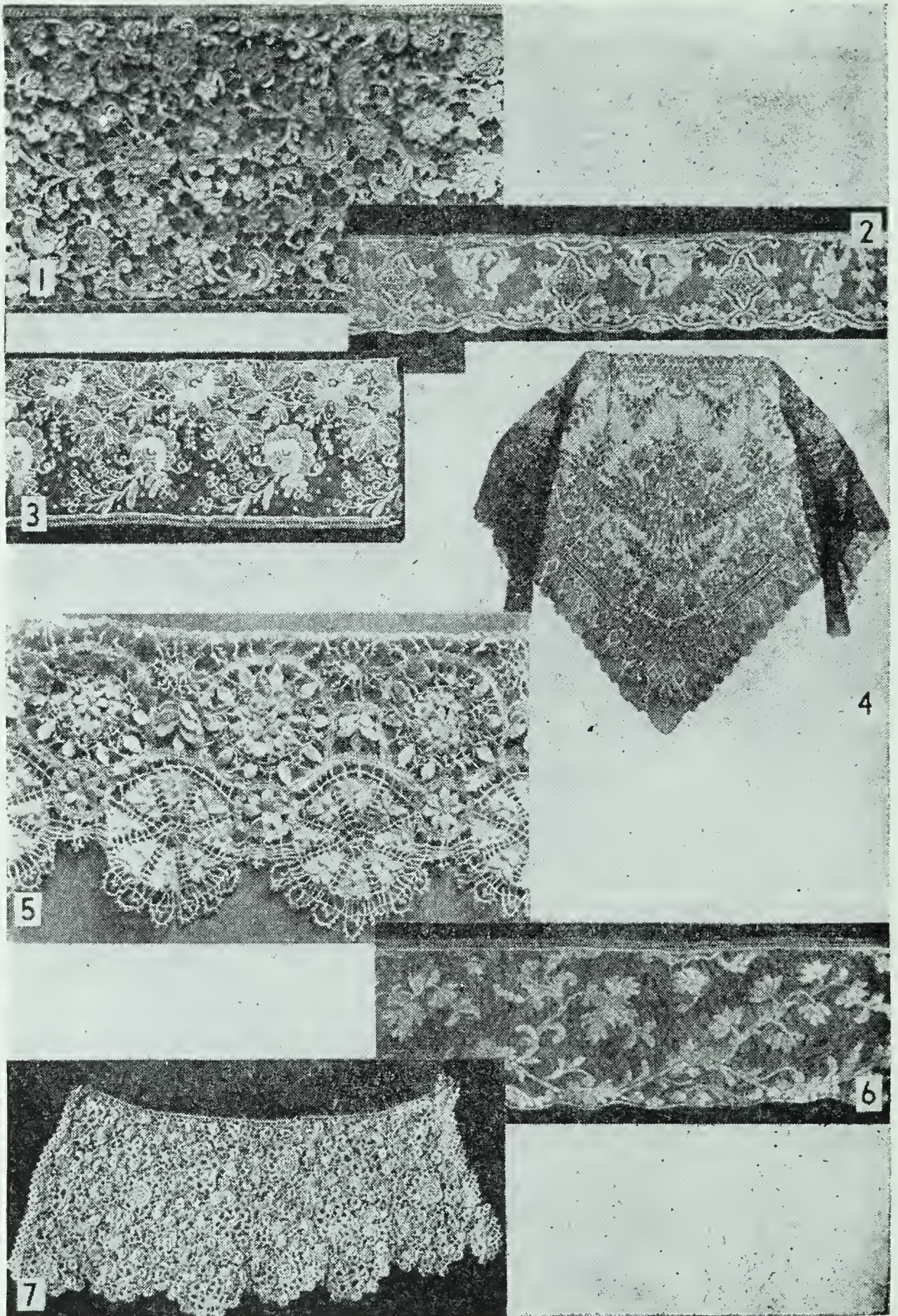
PROBLEM 6. HOW IS LACE CONSTRUCTED?

Authorities differ as to what constitutes a lace; however, all will agree that lace is an open mesh fabric with a well-defined pattern. As we know it today, lace is produced by braiding, knotting, knitting, or looping, or by twisting or stitching. Because all lace includes a design, plain bobbinet is not classed as lace.

It is thought that the art of lace making developed from early attempts at ornamentation of fabrics. These first laces were simply loops of yarn or thread attached to the hem of garments. The first approach to lace making seems to have been of a type of embroidery stitch on a foundation of linen which was afterward removed. Many years later true lace, which is constructed one loop or part of the mesh at a time, was evolved. What we now know as lace making seems to have originated in distant countries, at the same time but involving



Three qualities of knitted net. Top and center, rayon; and bottom, cotton. Fabrics similar to these are now being constructed on tricot knitting machines.



Courtesy The Metropolitan Museum of Art

Handmade laces. Needle point: (1) Venetian; (2) Point D'Alençon; (3) Point de Gaze. Bobbin lace: (4) Chantilly; (5) Cluny; (6) Valenciennes. Irish crochet: (7) Nineteenth Century.

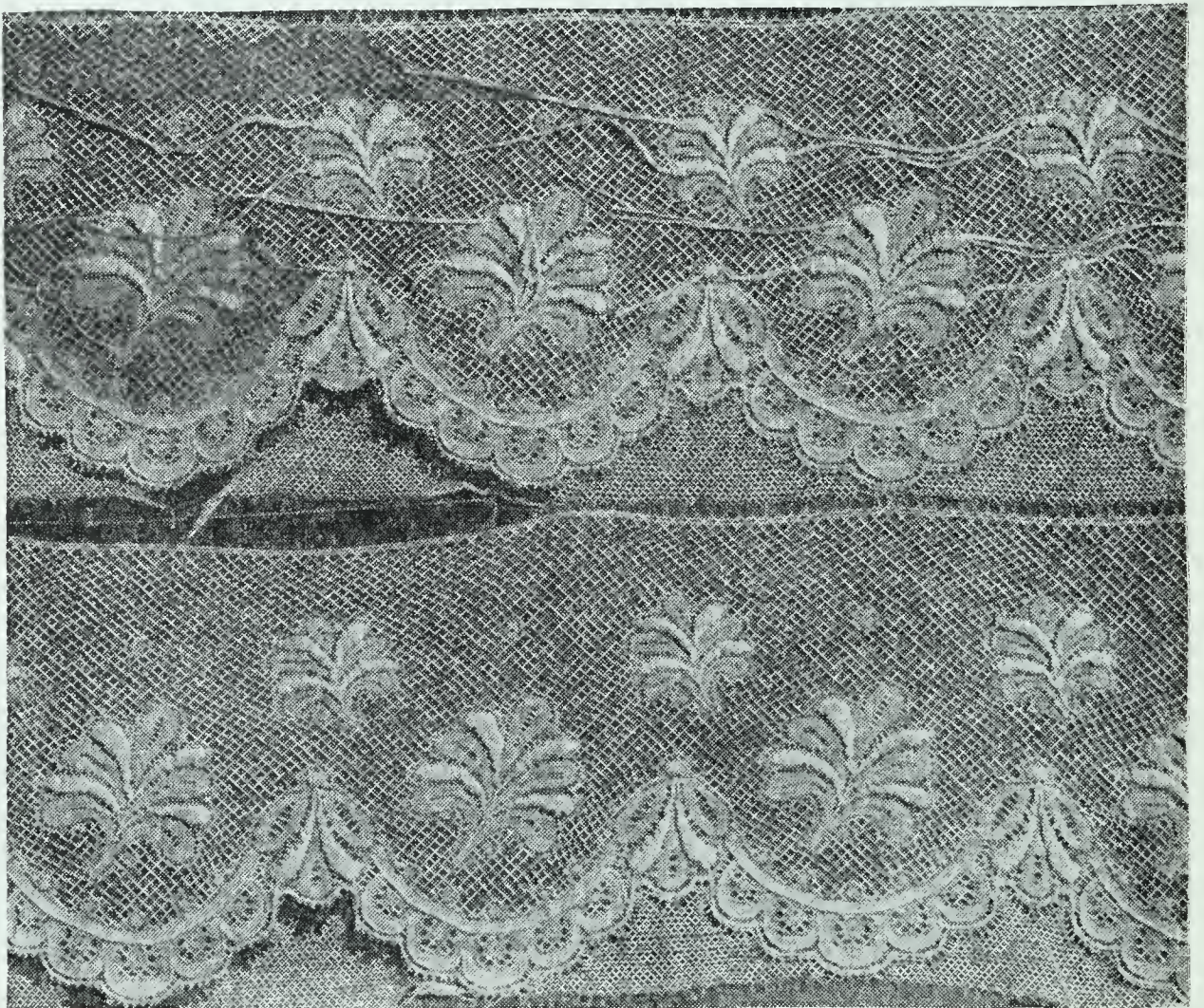
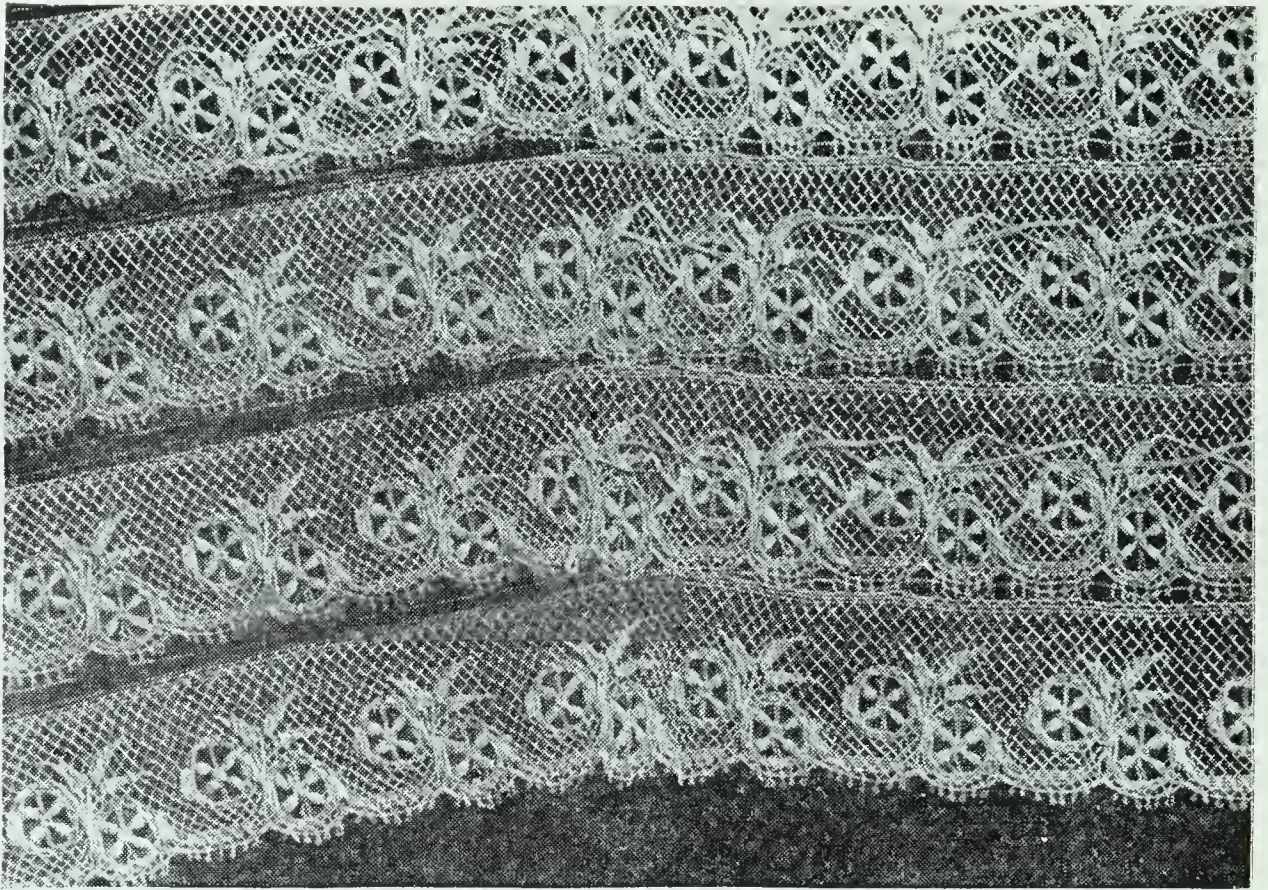
two widely different systems. In one method, known as *needle point*, by means of a needle and one thread a pattern is constructed mesh by mesh. Popular laces of this type include Venetian Point, Alençon Point, and Rose Point or Point de Gaze. In the other method, known as *bobbin*, many threads, each attached to a bobbin and worked over a pillow, are manipulated at the same time to create the mesh and the design. (See page 64.) Lace of this type is often called pillow lace.

Needle-point lace, when first constructed, is considered to have been evolved from a thought in the mind of the worker and so is regarded as a true art creation. Later, lace of this type was constructed from a set pattern. By means of the two widely different processes, needle point and bobbin, laces can be produced that are so nearly alike that it requires an expert to recognize the method used. However, needle-point laces not so commonly duplicated by the bobbin process of construction include Venetian Point, Alençon Point, and Rose Point laces. Bobbin laces that are seldom approximated by needle-point work include Chantilly, Cluny, and Valenciennes. (See the illustrations on page 64.)

To the handmade laces, needle point and bobbin, must be added crochet and filet laces, which are also handmade. The processes by which these are made differ in some regards from those previously described.

Crochet lace is made by looping the thread with a crochet hook. It is similar to needle-point lace but is not equal in fineness. Some Irish crochet lace resembles in effect the needle-point laces of Spain and Venice.

The making of filet lace has persisted since before the sixteenth century. There are two types of filet. In one type the mesh is plain and the pattern is worked in with a linen thread; in the other the mesh is knotted and the design worked in with a regular darning stitch. The making of filet is no simple task, as in one yard of "six-hole" narrow filet lace there are 2,500 knots to be tied, a pattern to be darned in, and the edge to be buttonholed. If the straight edge is constructed as the mesh is made, a firm finish results. If the straight edge is made later, as is the case with cheap filet, the cut threads of the filet



Top, process of separating, clipping, and scalloping the web of fine machine-made Valenciennes lace. Bottom, similar details for machine-made Normandy Valenciennes lace.

mesh project through the loose buttonholing, making a less satisfactory finish.

Every kind of fiber that can be made into a yarn can be employed in lace making and all types of handmade laces are reproduced in machine-made ones. Torchon, Cluny, and Valenciennes are examples of machine-made laces that imitate the original handmade pillow or bobbin laces so successfully as to gain a wide market. Machine-made filet and crochet are less frequently found. The low price of the Chinese labor that produces the great volume of these laces is such as to make possible little lowering of production costs through machine manufacture.

Would you prefer handmade lace to machine-made lace? If you were to examine the same pattern, manufactured by hand and by machine, how would the pieces differ? The handmade lace is characterized by slight irregularities in its construction, and is generally much higher in price. Do you think it would be more durable? What justifies the greater cost?

When choosing lace, whether machine-made or handmade, certain points that affect the quality of the fabric must be noted. The edge must be firm and without cut ends; the yarns should not vary greatly in size; and the mesh should not be large enough to catch and be torn easily.

In general, the ultimate use of the lace determines the type that should be chosen. Lace is commonly used for decoration either for clothing or household purposes, but periodically becomes important as a clothing material. The character of the laces and the fibers from which they are made vary with the fashions of the time.

A comparatively recent development of lace making employs cellulose acetate rayon and regenerated rayon, or a cellulose acetate rayon and cotton. The cellulose acetate yarn is embroidered in pattern on the cotton or regenerated rayon foundation which is afterwards chemically removed, leaving the embroidered pattern as lace. A more recent type employs the use of synthetic yarns made from seaweed. These yarns are soluble in hot soap suds and are thus easily removed from the original construction, leaving an open-mesh, lacy fabric.

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Unit Two

HOW YARNS ARE CONSTRUCTED

THE multiple differences in fabrics when they are ready for the consumer are the result of variations in the fibers, yarns, construction, and finish employed in their makeup. The characteristics of the fabric desired include not only appearance but also the weight, feel, draping qualities, and durability. An examination of fabrics on the shelves in a cotton goods section of any large store to determine the kinds of yarns used would be most enlightening and surprising. Short fibers twisted into one continuous length will be found as the yarns in sheeting and most voile, the difference in the amount of twist accounting to a great extent for the difference in the texture of the cloth. A coarser voile may be found to contain a yarn made by twisting together two continuous lengths of yarn. One will find that every type of fabric examined contains yarns varying in some way, the difference being either large or small.

Fabrics on the shelves in all of the other sections will show the same or much greater variation in yarns, each chosen because of its ability to impart to the fabric certain desired characteristics.

Wide differences are found in fibers of various sources in their natural state, and these in turn are reflected in the special handling of certain fibers before they are shipped to the yarn manufacturers. Thus, cotton fiber is removed from the seed which comprises two-thirds of the weight of the fiber as it is picked, but wool may be sent directly to the manufacturer just as it was removed from the sheep. *Raw* fibers are the fibers as they reach the yarn manufacturer.



Courtesy Kansas State College

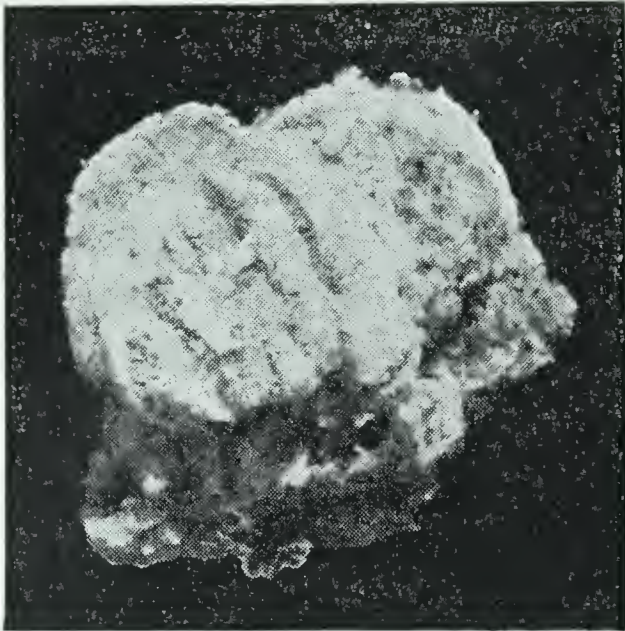
A heavy fleece, still holding the outline of the animal it has recently covered.

PROBLEM 1. HOW DO FIBERS DIFFER IN THEIR RAW STATE?

Wool. Wool in its broadest sense includes the covering of several types of animals, but for this discussion we shall consider only the wool of sheep.

The greater portion of wool, known as *fleece wool*, is clipped from the living sheep. A small portion, known as *pulled wool*, is removed by chemical and physical means from the pelts of slaughtered animals.

The entire clipping or fleece from one animal holds its shape because of the entanglement and matting of the fibers. A fleece is rolled and tied in a bundle, and many of these are packed into large sacks or bales, ready for shipment. (See page 72.) This wool, both fleece and pulled, containing body grease and sweat together with foreign matter such as dirt, sand, leaves, twigs, and the like that have been picked up by



Courtesy Department of Animal Husbandry,
Kansas State College

A fleece, rolled and tied.

can be made directly into cloth, in its raw state. The glue is softened but not removed, the two fibers are unwound simultaneously from a number of cocoons (three to ten), combined with a slight twist and wound onto a reel in the form of

the animal is known as *raw wool*. The impurities, both natural and foreign, must be removed before the fibers can be spun into yarn. This cleaning usually is done by both chemical and mechanical means.

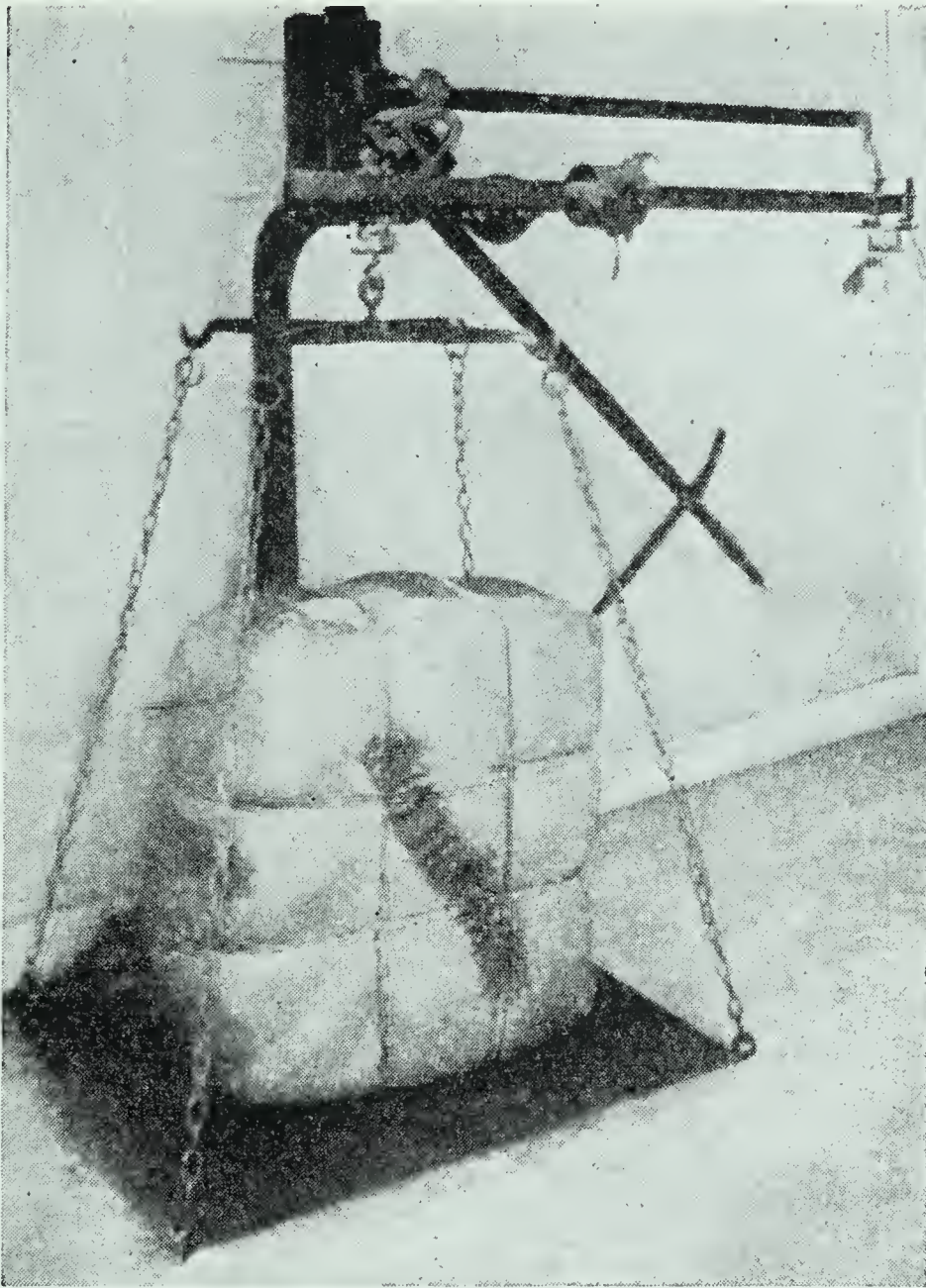
Silk. Silk as it is spun by the silk worm in the formation of its cocoon is the raw silk of commerce. It consists of two filaments cemented together with a gum or glue.

This is the only fiber that



Courtesy Bureau of Agricultural Economics, U. S. D. A.

Packing clipped wool.

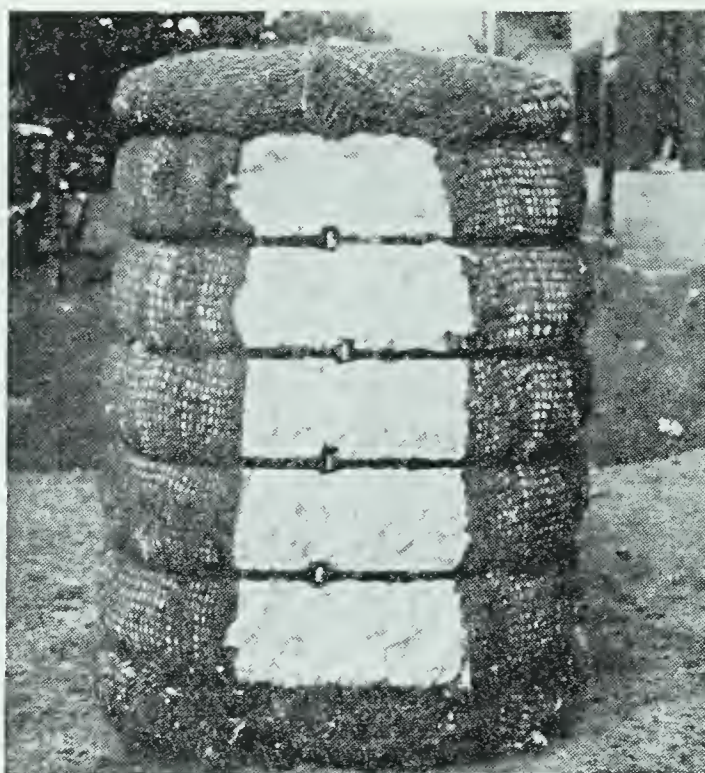


Courtesy The Silk Association of America, Inc.

A bale of raw silk.

skeins. This process of unwinding the cocoons and rewinding the silk onto reels is known as reeling. Silk, before the glue has been removed, no matter whether in the form of cocoons, skeins of reeled silk, or fabrics, is really raw silk. Skeins of silk are made into books, which are packed in bales wrapped with tea matting and shipped to the yarn manufacturer. (See the illustration above.)

Raw silk to which little or no twist has been added may be woven into cloth and the gum removed when the fabric is fin-



Courtesy Bureau of Agricultural Economics, U. S. D. A.

Bale of cotton.

fibers that have been removed from the cotton seed, together with foreign material such as dirt, sand, and broken bits of leaf, stem, and boll. When the cotton is picked it is securely fastened to the seeds, which are removed by ginning before the cotton is baled for shipment. A plantation bale weighing about 500 pounds is covered with burlap and bound with steel bands. (See illustration above.) These bales of ginned cotton are the raw cotton of commerce. The fiber is not scoured before it is spun into yarn but is cleaned by mechanical processes, the most important of which is carding.

Linen. The linen fiber, which is obtained from the stem of the flax plant, passes through many processes before it reaches the yarn manufacturer. The entire plant is pulled and dried; the seeds and leaves are removed; and the stem is treated so that the fibers which lie just under the bark may be removed. This is usually done by retting, which consists of the destruction of the connective tissues by bacterial action. Although most of the bark has been removed, small portions remain, and the fibers together with these bits of broken bark are the raw flax fibers. Raw flax is packed in bales weighing

ished. The gum or sericin holds the fibers together until they are constructed into a fabric. After the cloth has been degummed, the length of the fibers prevents their pulling out. This accounts for the untwisted yarn in silk pongee and other fabrics. Silk is the only natural fiber that can by simple processes be made into a yarn without twist.

Cotton. Raw cotton consists of the short fi-



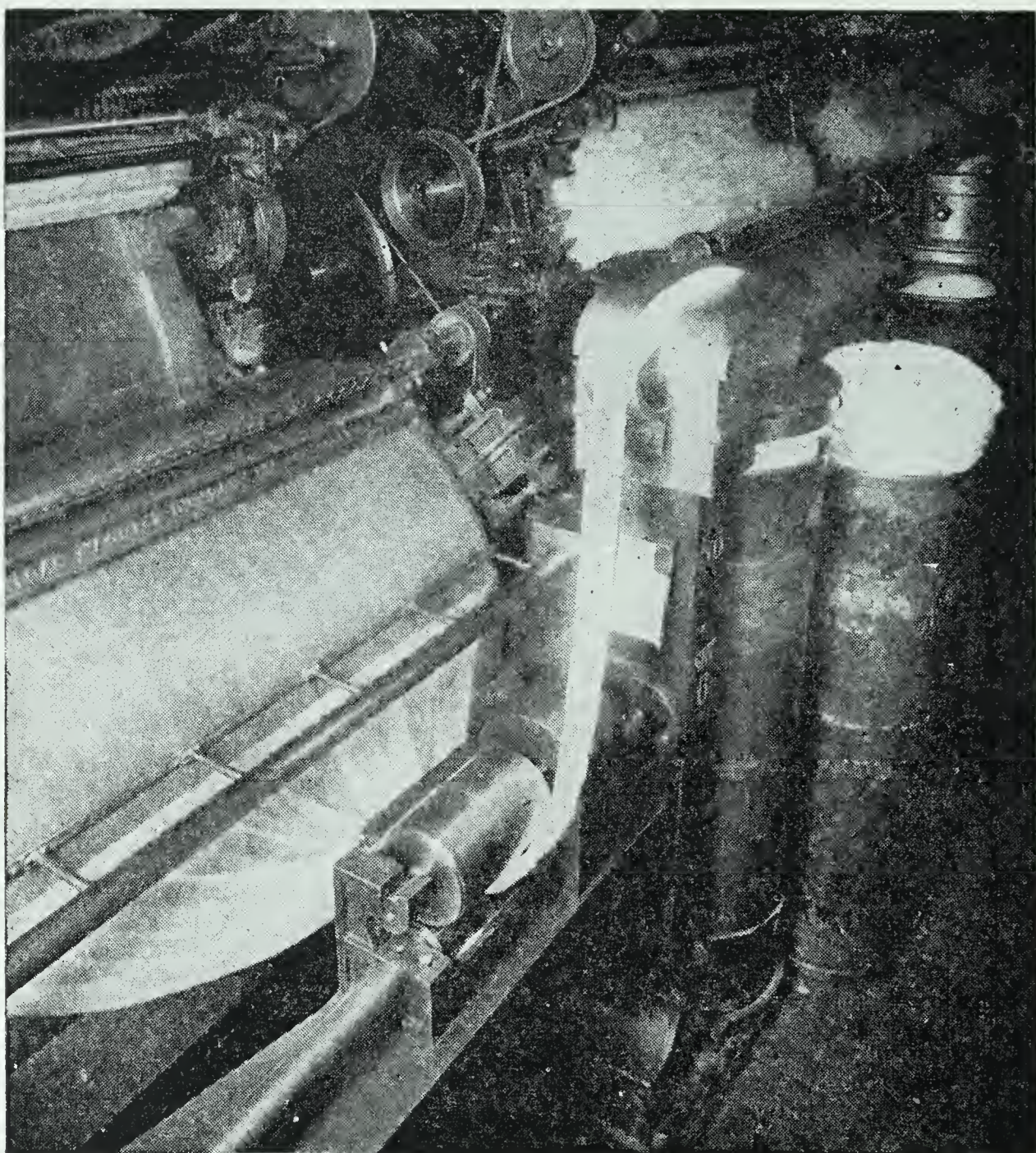
Courtesy Colonel W. B. Bartram

Baled flax. View showing part of fireproof warehouse where the flax is stored.

from 200 to 220 pounds. These fibers are further cleaned by mechanical means.

PROBLEM 2. HOW ARE SHORT FIBERS MADE INTO YARNS?

Manufacture. The following discussion of the manufacture of cotton yarn will give a general idea of the necessary steps in the construction of any yarn. The processes of constructing a continuous length from any short fiber, although differing in detail for each, are similar in nature for all. Raw wool must be sorted according to the quality, grade, and color of the fiber and then scoured. Raw cotton packed in tightly compressed bales passes first through the opening machines which include the bale breaker and opener pickers. In opening the bale, the wire and the jute covering are removed and weighed back as waste. Because of fire hazards this work should be carried on either in a separate building or in a part of the building protected by a fireproof wall. Cotton from several bales is thoroughly blended and handled together. This is necessary to produce a particular type of yarn when the correct fiber is not available, and also to obtain a uniform



Courtesy The Spool Cotton Co.

The cotton coming from the card in a gossamer web is drawn into a sliver.

product from a large quantity of cotton. The fibers may be mixed on the picker-room floor or may be fed through an opener and spread in even layers in a mixing bin. From here the cotton is raked down perpendicularly and fed to the pickers. These machines are sometimes fed by hand, but labor is saved and the material is delivered more evenly with automatic feeders.

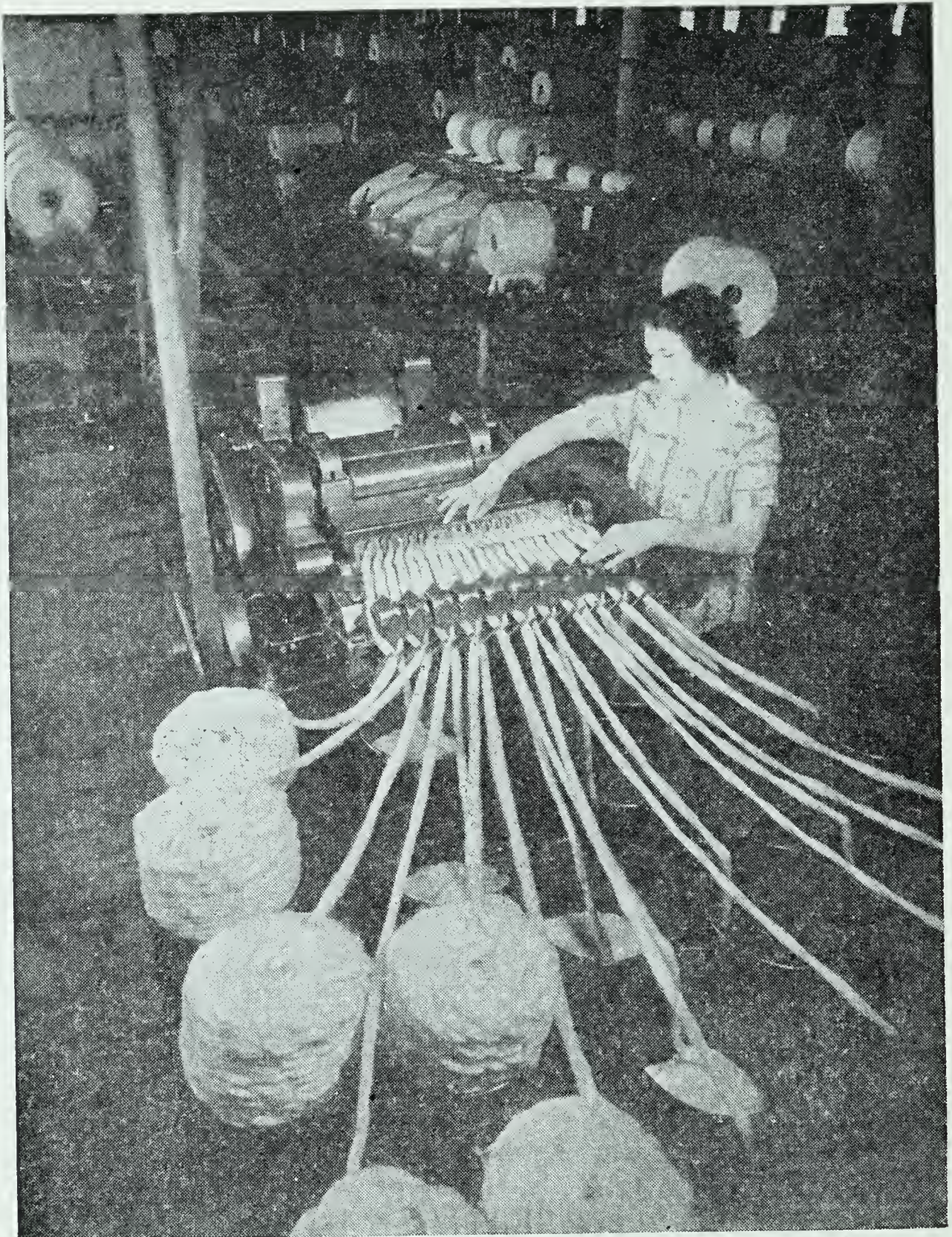
Opened cotton is further cleaned and handled mechani-

cally. The apparatus used is so arranged that the fibers pass over a slatted surface that permits the coarse dirt and sand to pass through. The present tendency is to limit the number of machines by combining several operations in one. These machines deliver the fibers, wound on a rod, in the form of a loose lap comparatively even in weight per yard. In this form they are taken to the carding machine, the main purpose of which is to clean the fibers thoroughly. (See page 76.)

Carding is one of the most important manufacturing processes. In the card the fibers are fed to a rapidly moving cylinder covered with fine pointed wire and carried against another set of similar wires that are moving slowly. The fibers are formed into a gossamer-like sheet from which they are drawn into a strand about one inch in diameter. This strand, known as a card sliver, is delivered through a coiler into a can. The purpose of the card is not only to clean the cotton thoroughly but also to deliver a definite amount in a form that can be handled by the next machine. Something of the quality of the sliver can be judged by determining how far it can be split without breaking.

The card sliver is coiled in tall cans from which it may go directly to the drawing frame. (See page 78.) The carding process thoroughly cleans the fibers, more or less straightens them, and lays them parallel to the length of the strand.

If a fine, even yarn is desired, the card slivers are subjected to a combing process which further parallelizes the long fibers and removes the short ones. Several carded or combed slivers are then combined and passed through machines that draw out the strands, distribute the fibers evenly throughout the length, and reduce the size of the combined strands to that of one strand entering the drawing frame. It is difficult to draw out the fibers and reduce the size after twist has been added. For this reason, up to this point the fibers are not twisted, as the product of each machine has sufficient bulk and strength to prevent the strand from pulling apart under its own weight during further processing. From here on the strand, known as a *roving*, is processed so as to even and reduce its size and add the desired amount of twist.



Courtesy The Spool Cotton Co.

Cotton drawing. Note the cotton slivers entering the drawing frame.

Spinning. Spinning, although used to cover all the yarn manufacturing processes, is in its correct sense the last process of manufacture—that of drawing the material out to the desired size and adding the required twist.



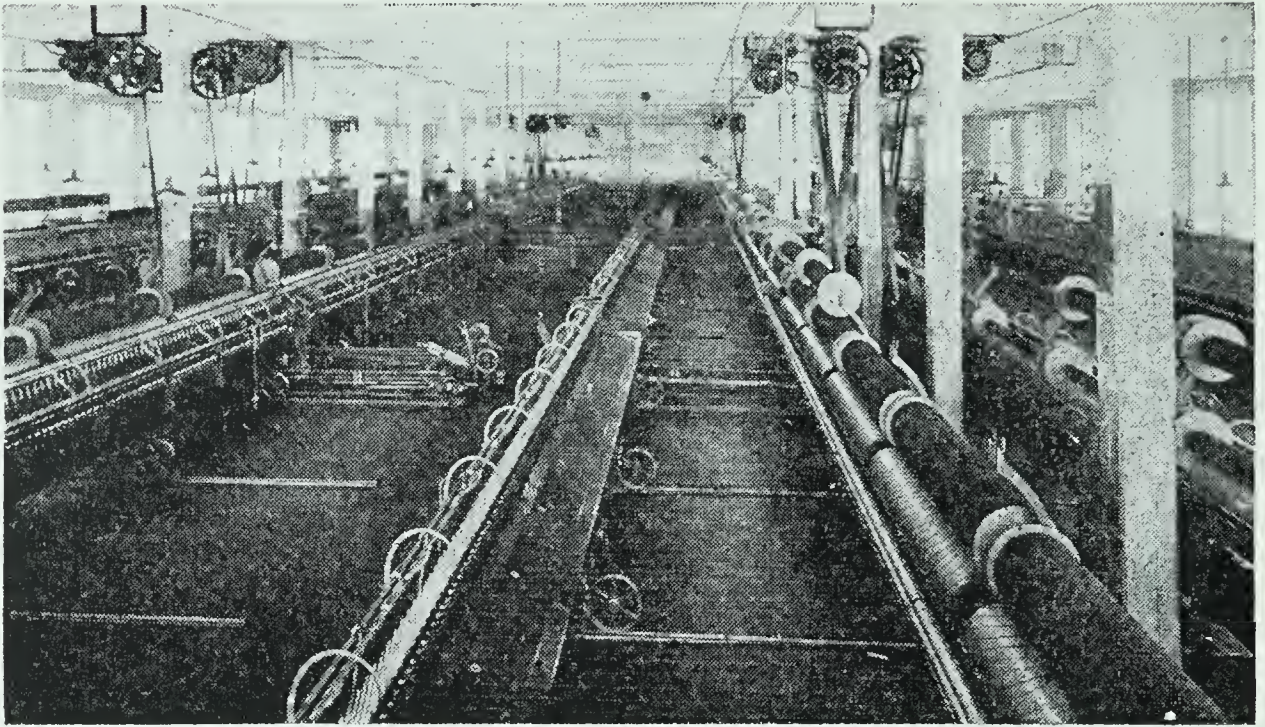
Courtesy Whitin Machine Works

Cotton-spinning frame.

Spinning, which is the last of the yarn manufacturing processes, includes drawing out or drafting, inserting of twist, and the winding on or packaging. There are four systems of spinning, namely, Flyer, Cap, Ring, and Mule. These fall into two main divisions: that of continuous frames which include the flyer, cap, and ring frames; and the intermittent or mule frame.

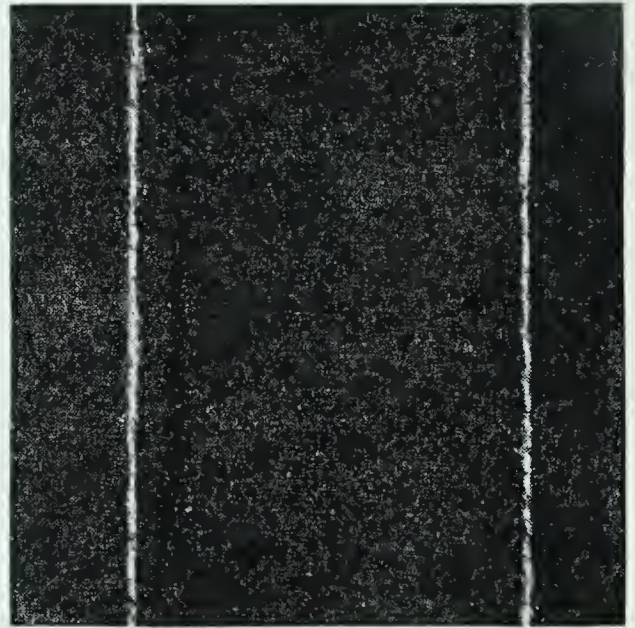
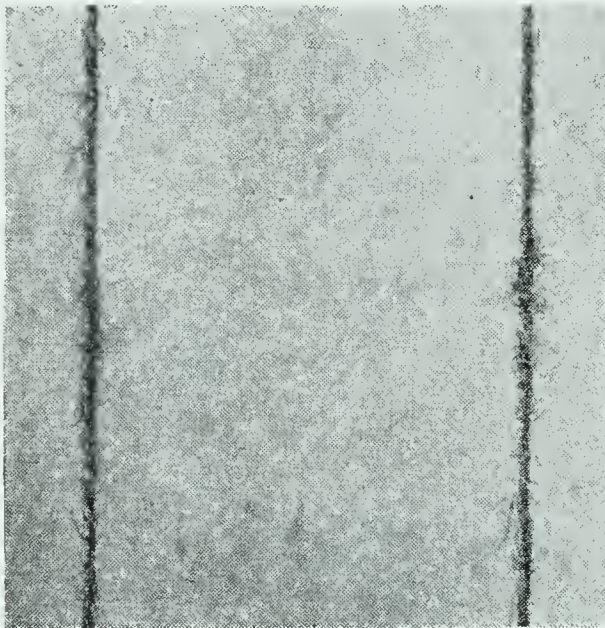
The flyer system, the original system of continuous spinning, is being replaced by other systems because of its low output. However, it is peculiarly suited to the production of yarns where high luster and great smoothness are especially desired.

The cap system is characterized by high speed and is especially adapted to the spinning of fine counts of yarns. The principal difference between this and the flyer frame is in the construction of the spindle, the method of inserting the twist, and the winding on of the yarn. The bobbins used in this system are smaller than those used in the flyer system. In ring spinning, a rapidly revolving spindle puts the twist into the yarn which is wound on the bobbin by means of a ring or hook serving as a drag to retard the winding process. The difference in the rapidity of the revolution of the spindle and the ring governs the winding on, and the ring traveler controls the twist per inch. This method results in a strong, firm yarn. The ring system of spinning is the most economical.



Courtesy *Textile World*

Modern high-speed mule.



Courtesy Johnson and Bassett, Inc.

Left, mule-spun yarn. Note fibers which are left in their normal position. Right, frame-spun yarns. Note that fibers are bound together, producing a harder yarn.

This system permits the production of a high-quality yarn in large packages at a low cost. Large packages permit the production of long lengths of knotless yarn which are a great advantage to the weaver and knitter.

Mule spinning, or the intermittent system, produces an excellent soft yarn not easily surpassed. As the name implies, the drawing, twisting, and winding-on are not performed continuously as in the case of the flyer, cap, and ring systems. The drawing and twisting are accomplished when the carriage travels from 60 to 64 inches from the rolls. The yarn is completely formed when the carriage reaches the end of its outward journey and the yarn is wound onto the cap or yarn package, as the carriage returns to its original position in front of the draw rolls. (See first illustration on page 80.)

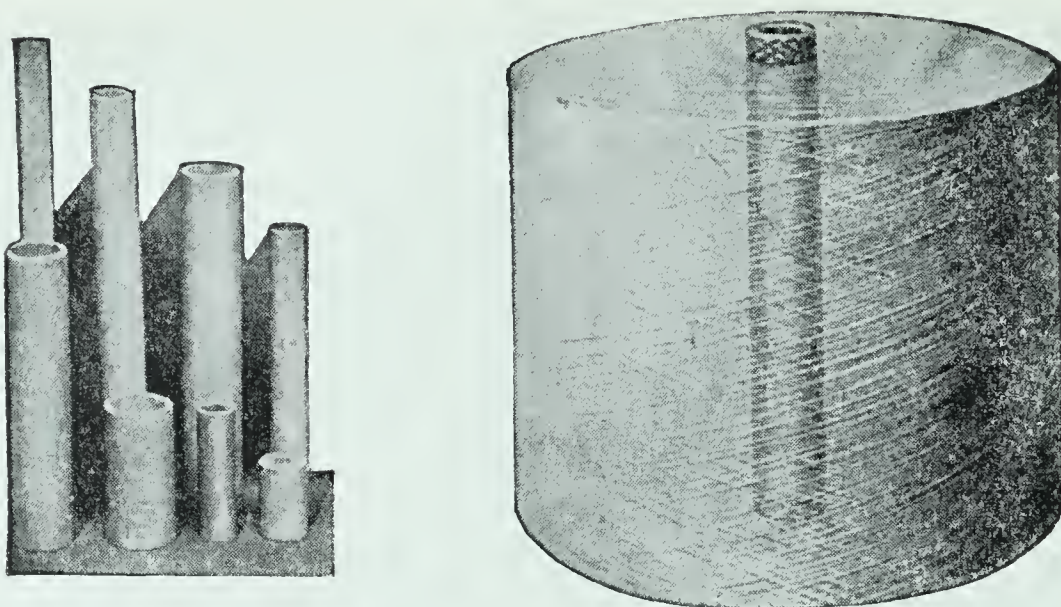
The intermittent action of mule spinning has its advantages and disadvantages. These machines require more space and time for operation; however, the product may be a softer, finer, and more even yarn that is especially adapted to knitting and other uses.

Spinning is another process in which there is a tendency to combine many operations in one apparatus, eliminating some pieces of machinery. In spinning, a difference is made in the yarn prepared for warp and filling. There is usually a greater amount of twist in that prepared for use as warp, as it is subjected to more friction and strain. After spinning, the filling yarn is ready for use in the shuttle, but the warp requires further processing.

Many lengths of warp yarn are tied together and wound onto spools or bobbins as a continuous length. From these it is wound onto the warp beam. The warp is treated with sizing to enable it better to withstand the friction and strain produced during weaving.

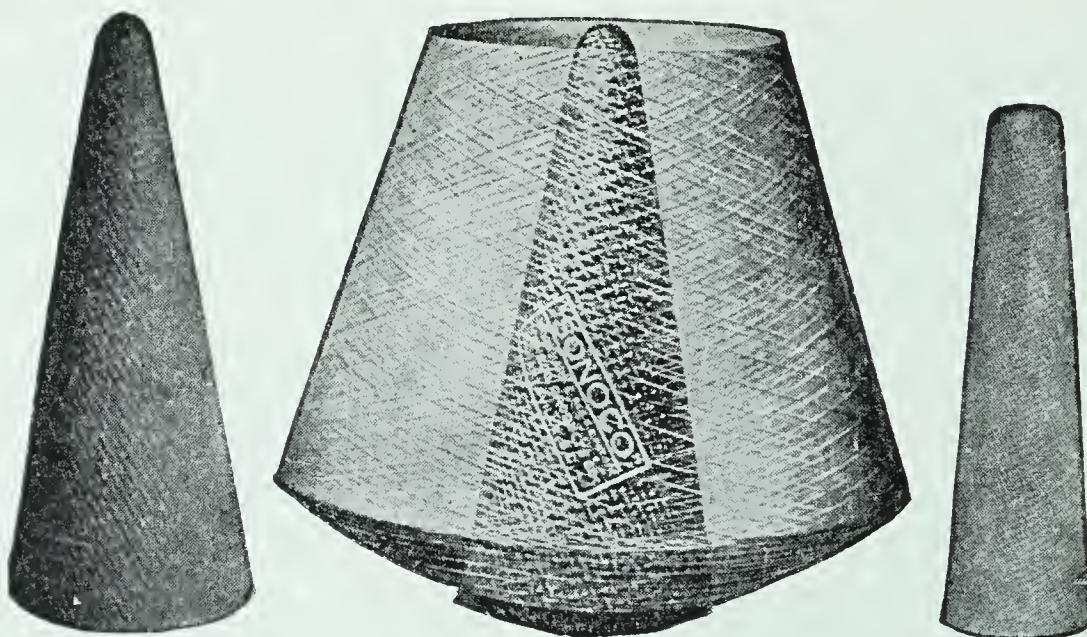
Twist. The various terms used to designate the direction of twist, such as right hand and left hand, clock and anticlock, have been replaced by the terms "S" and "Z." (See page 83.) These terms have been adopted by Committee D-13, the textile committee of the American Society for Testing Materials. They have also been adopted extensively by the industries in this country and in Europe.

The twist of the yarn plays an important role in determining the character of the finished cloth. Differences in fabrics are produced by variations in the amount and direction of



Courtesy Sonoco Products Co.

X-ray view of wound tube package and of various sizes of Sonoco Parallel Tubes. These tubes are made of paper throughout.



Courtesy Sonoco Products Co.

X-ray view of package and view of Sonoco yarn-saver cone. The cones are made of paper throughout. The tip is rounded and burnished so that the yarn will slide freely over it.

twist and the manner in which yarns of differing amount and direction of twist are combined in the construction of the cloth. An outstanding example of this is that of crepe fabrics that have a creped or crinkled surface, known as pebble, obtained by the use of highly twisted yarns. The pebble is pro-

duced in the finishing process as the result of the swelling and shrinking of the twisted yarns. If a decided pebble is desired the cloth may be constructed from alternating yarns of "S" and "Z" twist. When fabrics of this type are finished, the yarns draw up in opposite directions and form an uneven pebble.

Canton crepe, flat crepe, French crepe, Georgette, and chiffon are standard fabrics in which the characteristic crinkled surface is obtained by means of the variation in the yarns used. All are of plain

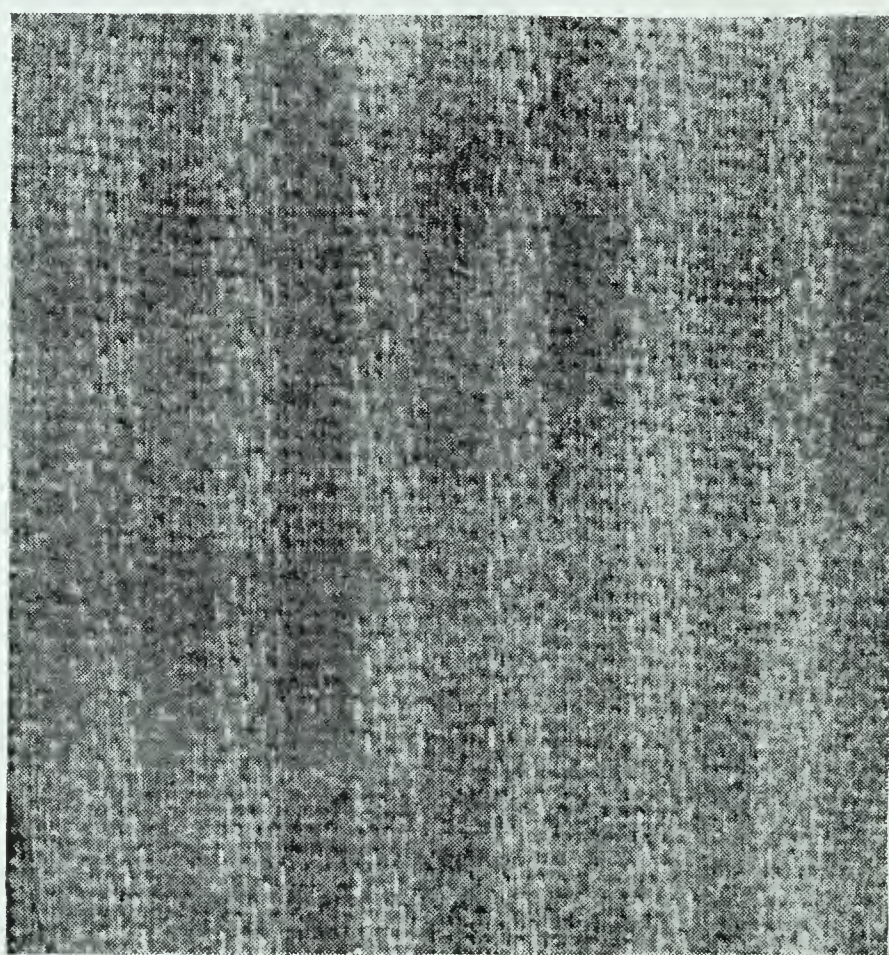
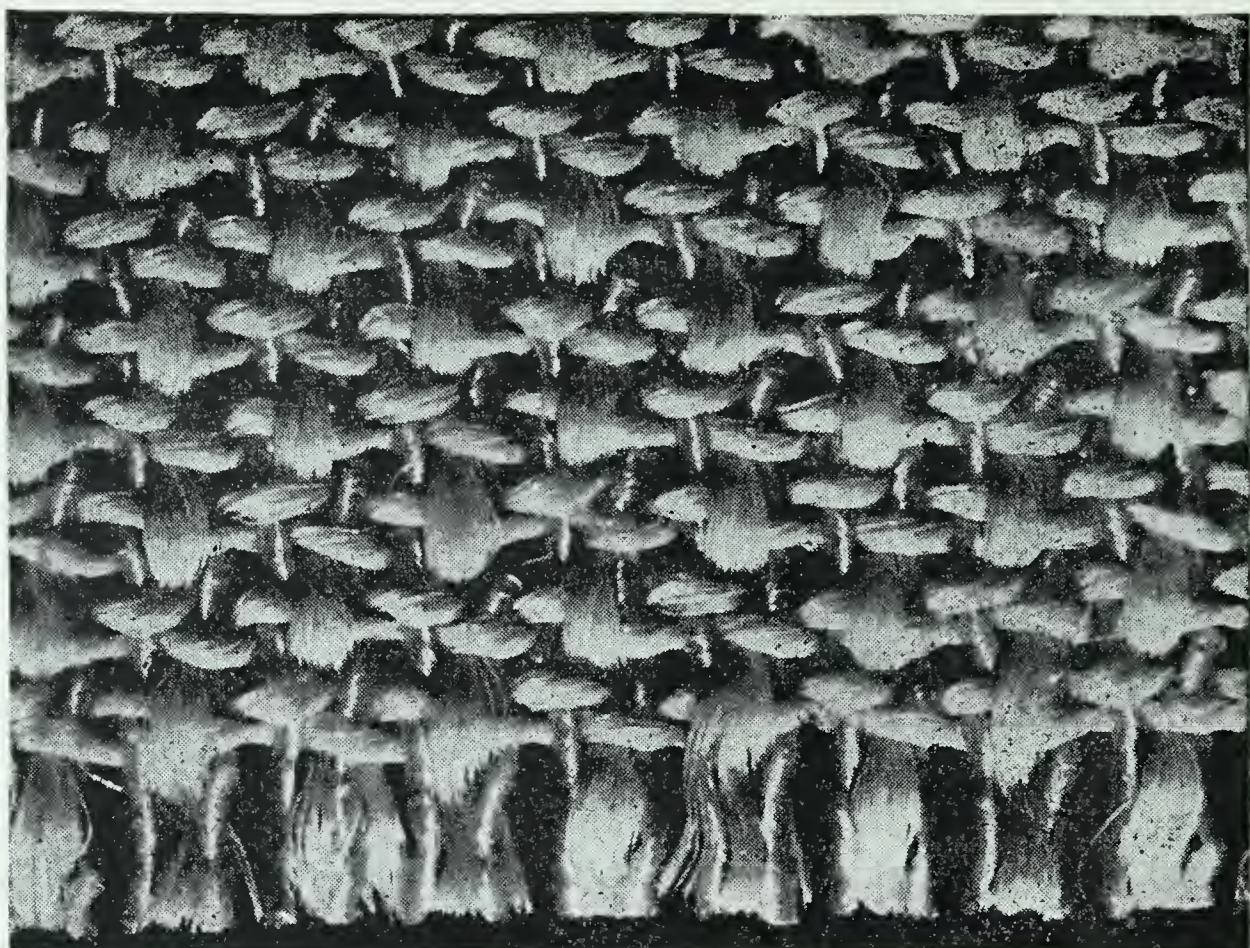
weave, but they vary in the number of ends and picks and in the size and direction of twist of the yarns.

Size or count. The description of the yarn includes its size or count. A skein of cotton yarn, 840 yards in length, known as a hank, is the basis for determining the count of cotton yarn by the cotton system. The size is the number of these hanks required to weigh one pound. That is, if a hank or 840 yards weighs one pound, the yarn is a number ones, written as 1^s; if two hanks weigh one pound, the yarn is a 2^s.

The size or count of yarns made from other fibers is determined in a similar manner. The number of yards of yarn in a hank varies for the different textile fibers and is so arranged that the size of the yarns, for convenience, usually falls between 1 and 100. This method of measuring the size of yarns does not permit an easy comparison of different types of yarns.



Yarns of "S" and "Z" twist.



Top, the two fine, tightly twisted S and Z yarns and the large loosely twisted yarns used in this fabric resulted in an unusual design effect. Bottom, design produced by grouping of S and Z twist yarns.

For example, a 50^s cotton yarn is smaller than a 50^s woolen yarn.

A universal system for numbering all yarns that would be acceptable to manufacturers and various organizations and testing laboratories would greatly simplify the determination of yarn number and would eliminate the need for conversion tables.

The "Typp" (pronounced tip) was at one time accepted by some organizations and testing laboratories as a solution to this problem. In this system the yarn number is given in the number of thousand yards per pound. The formula for all yarn size determinations is:

$$\frac{\text{Length in yards} \times 7,000}{\text{Weight in grains} \times 1,000} = \text{yarn number}$$

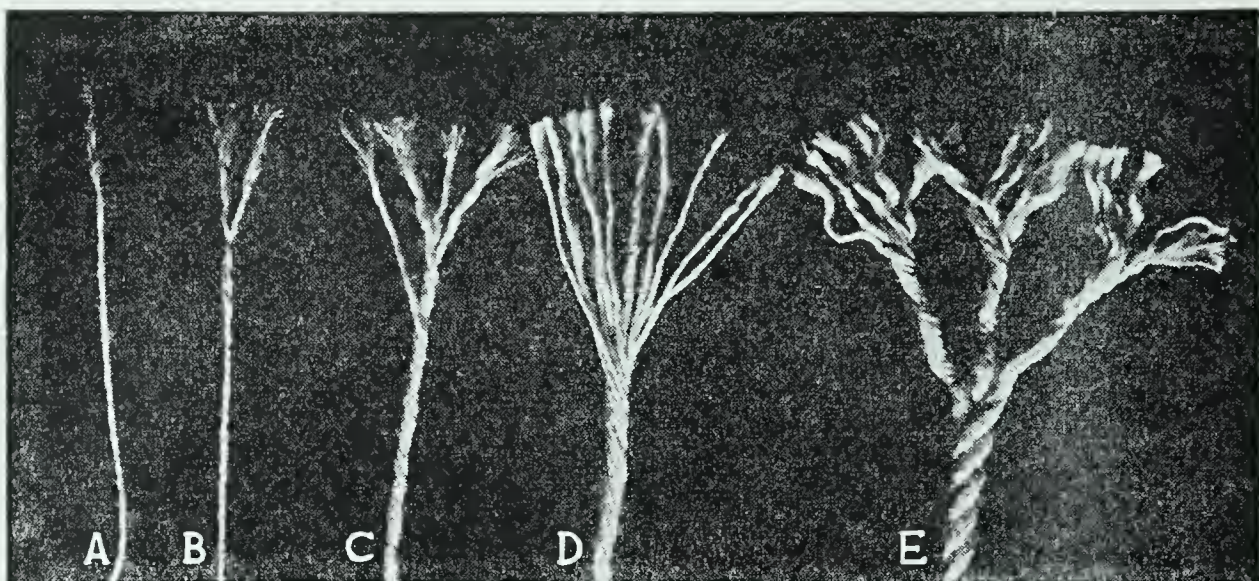
The Grex system in which the yarn number is given in the grams per 10,000 meters has been given much publicity. This system has been both favorably and unfavorably received. Directions for its use are given in A.S.T.M.

A sewing thread differs from a yarn principally in its use. Threads are continuous lengths of fibers more or less twisted together for use in joining cloth in the construction of some article. They vary in the fiber from which they are made, and also as regards the ply, color, twist, finish, and size.

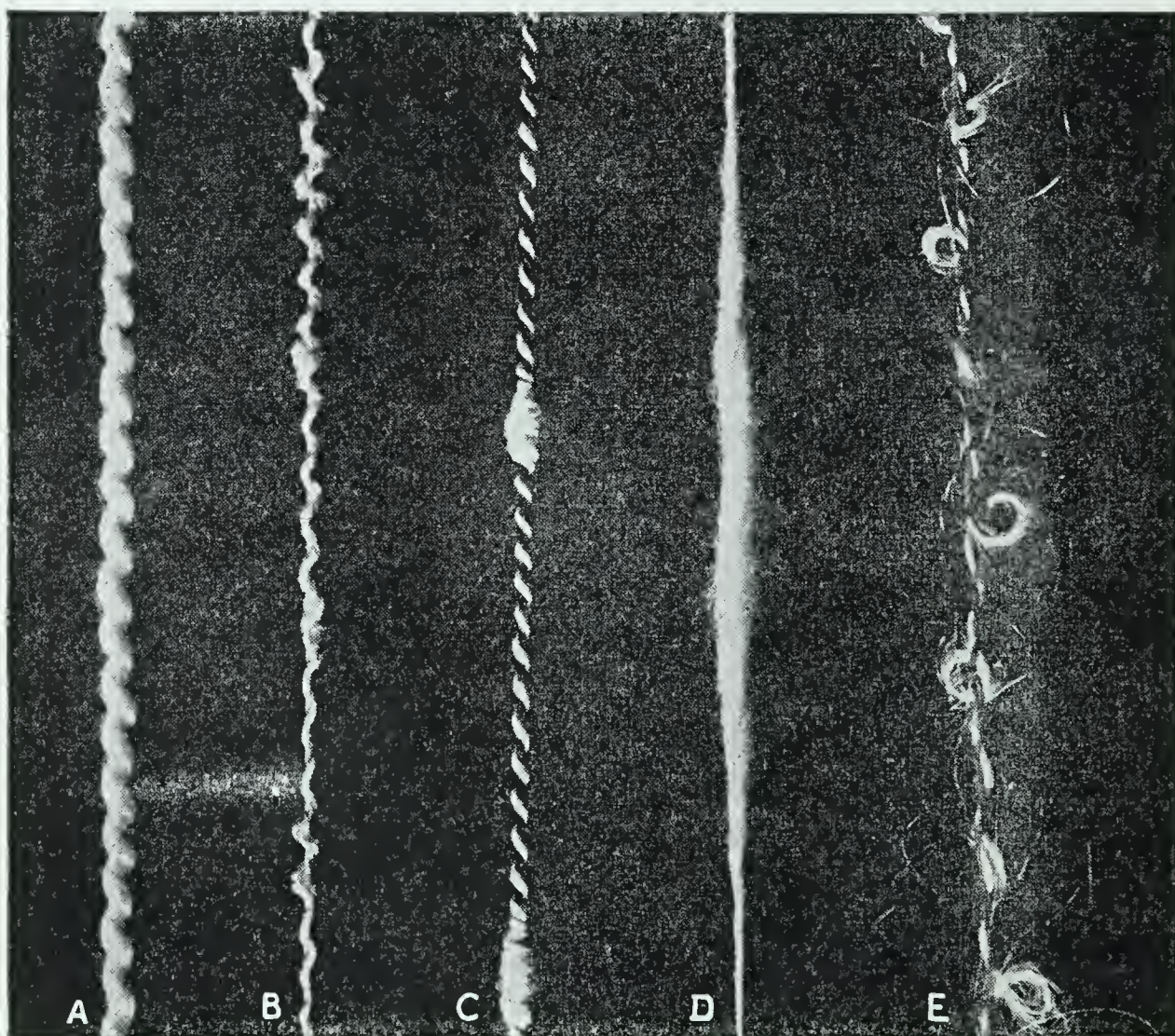
In the past, fine yarns of more than 100^s were not spun in the United States, but now some yarns as fine as 200^s are spun in this country. This increase in the range of yarn size has accompanied the development of the American spinning industry. Yarns vary in the yards that may be spun per hour and the weight per pound, depending upon the fibers used, the counts, the twist per inch, and the method of spinning. The usual method of reporting the amount of yarn produced is to give the number of active spindles.

PROBLEM 3. HOW IS VARIATION IN YARNS OBTAINED?

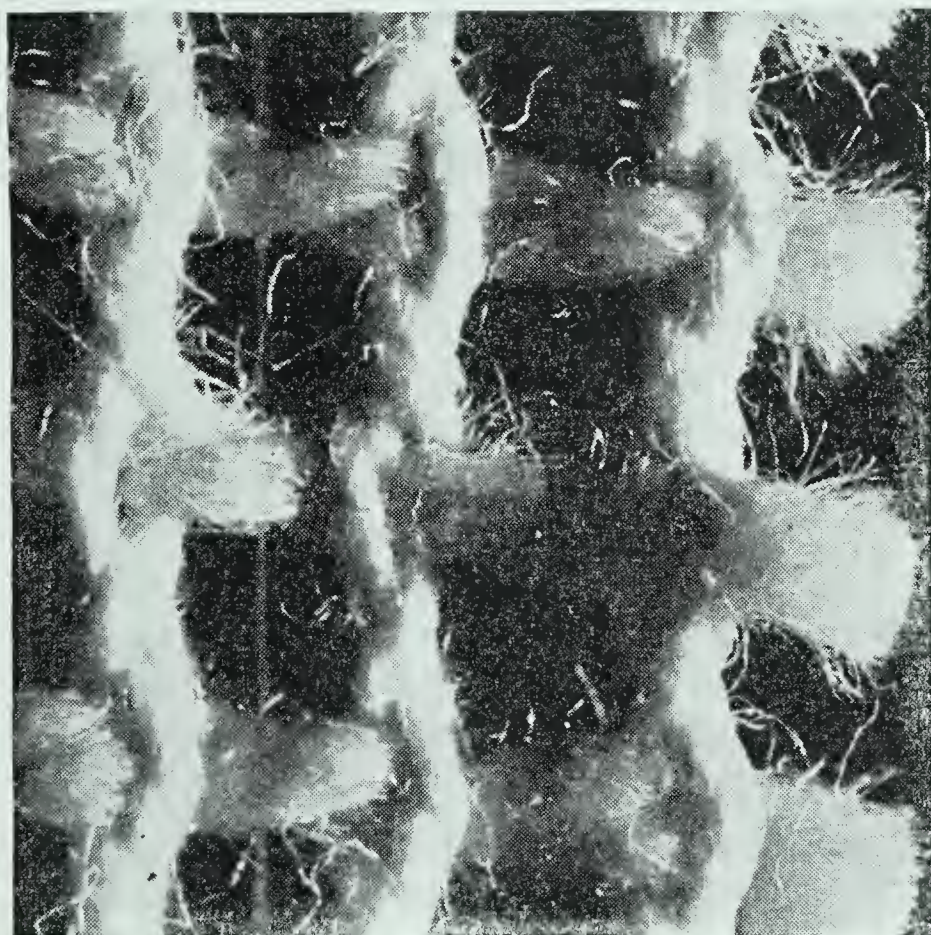
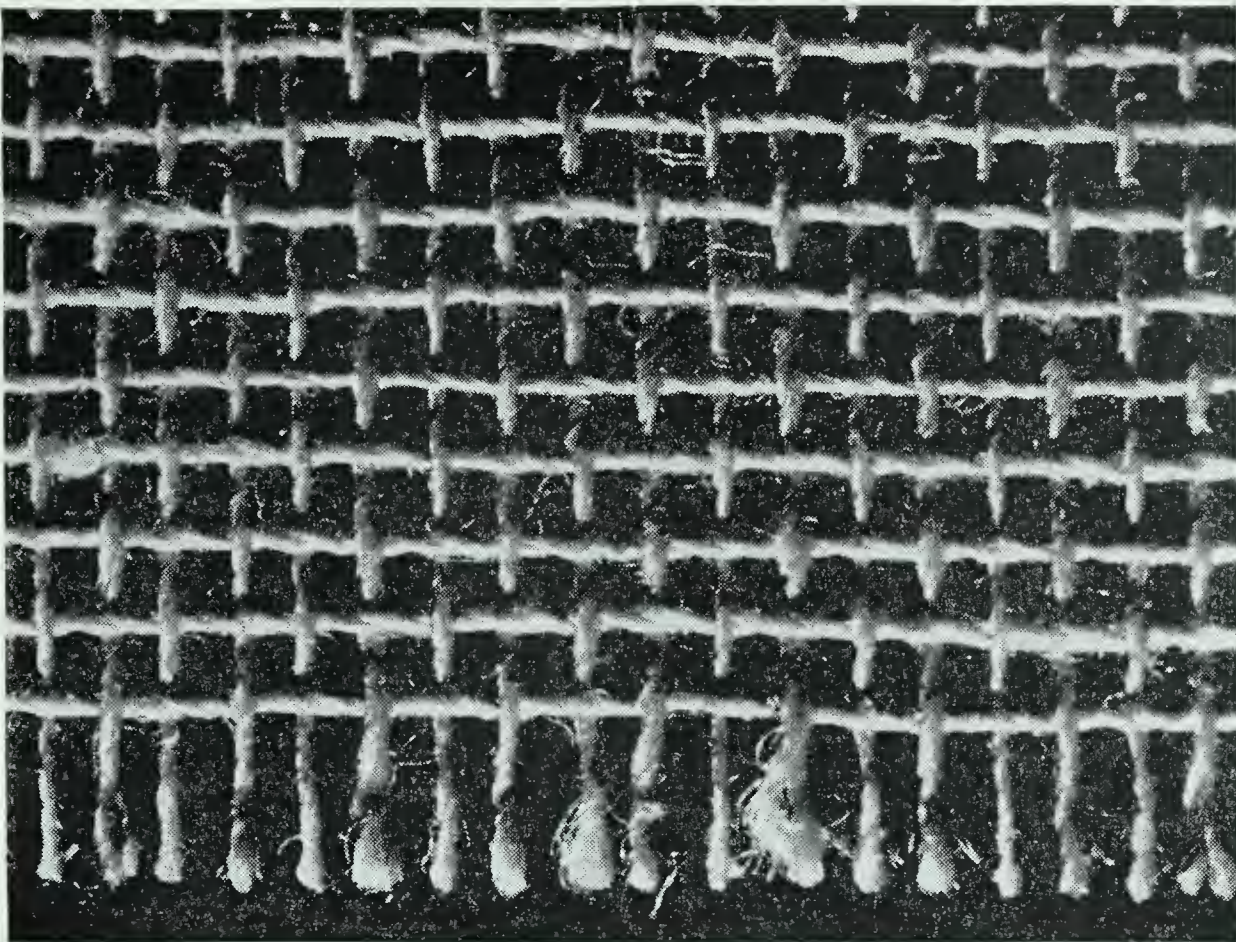
Yarns are classified in two different ways: according to the number of strands they contain, as *single*, *multiple strand*



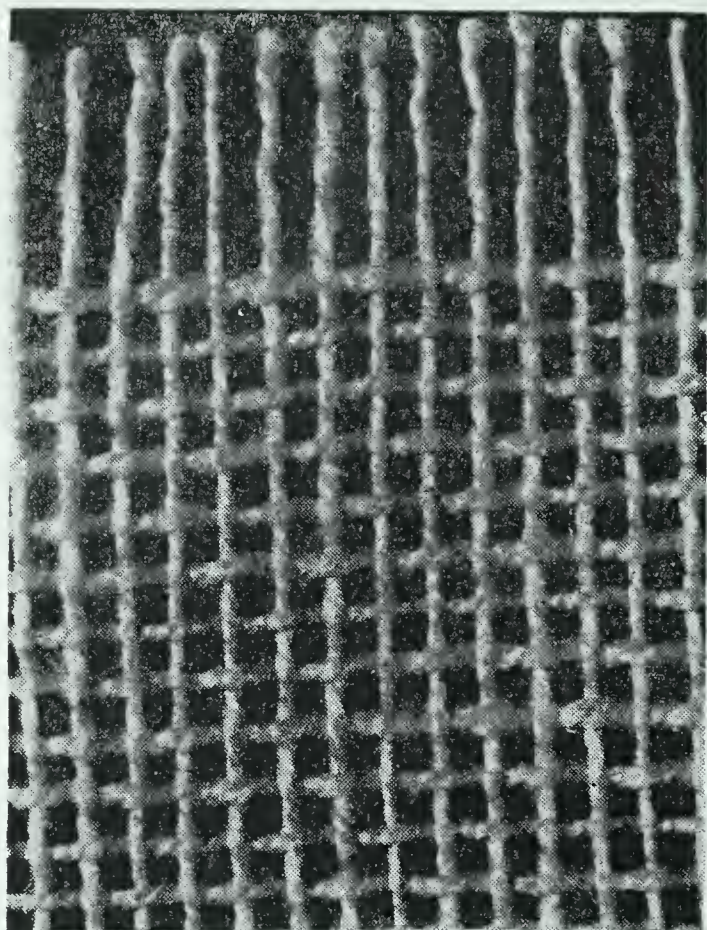
Simple yarns. A, single strand; B, two ply; C, four ply (multiple strand); D, multiple strand; E, cable (three strands of multiple strand).



Complex yarns. A, corkscrew; B, gimp; C, knot or spot; D, slub; E, loop.



Top, ply yarns used for strength in a fine voile. Bottom, ply simple yarns are used in the warp of this gauze-woven curtain material.



Two-ply yarn used for strength.

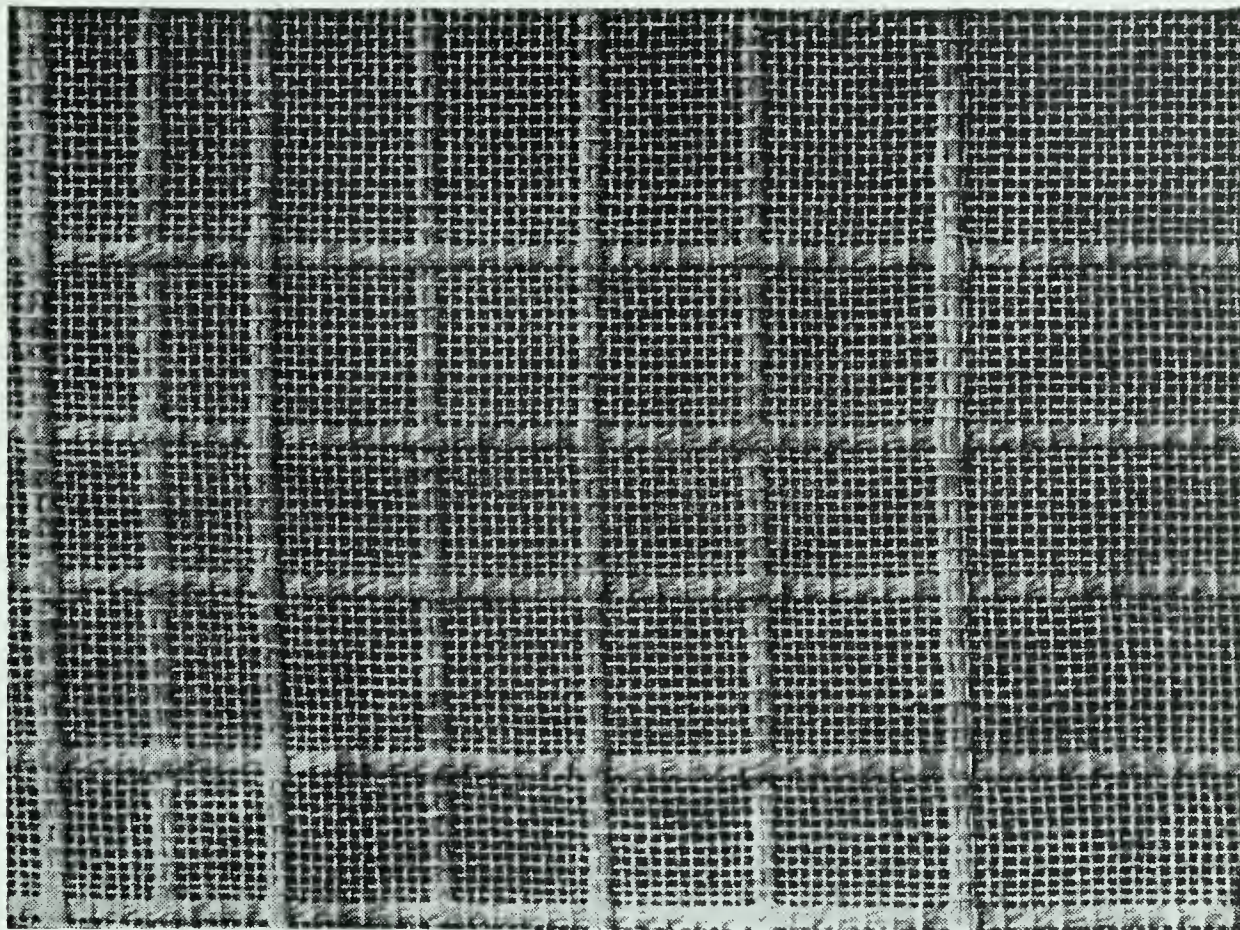
or *ply*, and *cable*; and according to their structure as *simple* and *complex*. (See illustrations on page 86.) For this discussion a strand will represent a continuous length of fibers more or less twisted together. Simple yarns are the type commonly used for utility fabrics. As the term implies, simple yarns are alike in all their parts. Complex yarns are used to produce a decoration or unusual effect in the fabric. They may vary in the structure of a single

strand, in the character of multiple strands, or the manner in which these are combined.

Simple yarns. These yarns may be single strand yarns composed of one continuous length of fibers with or without twist or they may be multiple strand or ply composed of two or more strands twisted together; or two or more of these ply or multiple strand yarns may be combined again into a cable yarn.

Single ply, simple yarns comprise the bulk of our fabrics. Ply or multiple strand, simple yarns are used to give added strength to cloths such as voiles and curtain material (See page 87), canvas for cots, and tubular fabrics for fire hose. Ply simple yarns may be used to form a design in a stripe or check. (See the illustration on page 87.)

Complex yarns. Complex yarns may consist of one strand of fibers which varies in its construction, being alternately loose and bulky and tightly twisted and fine along its length. How-

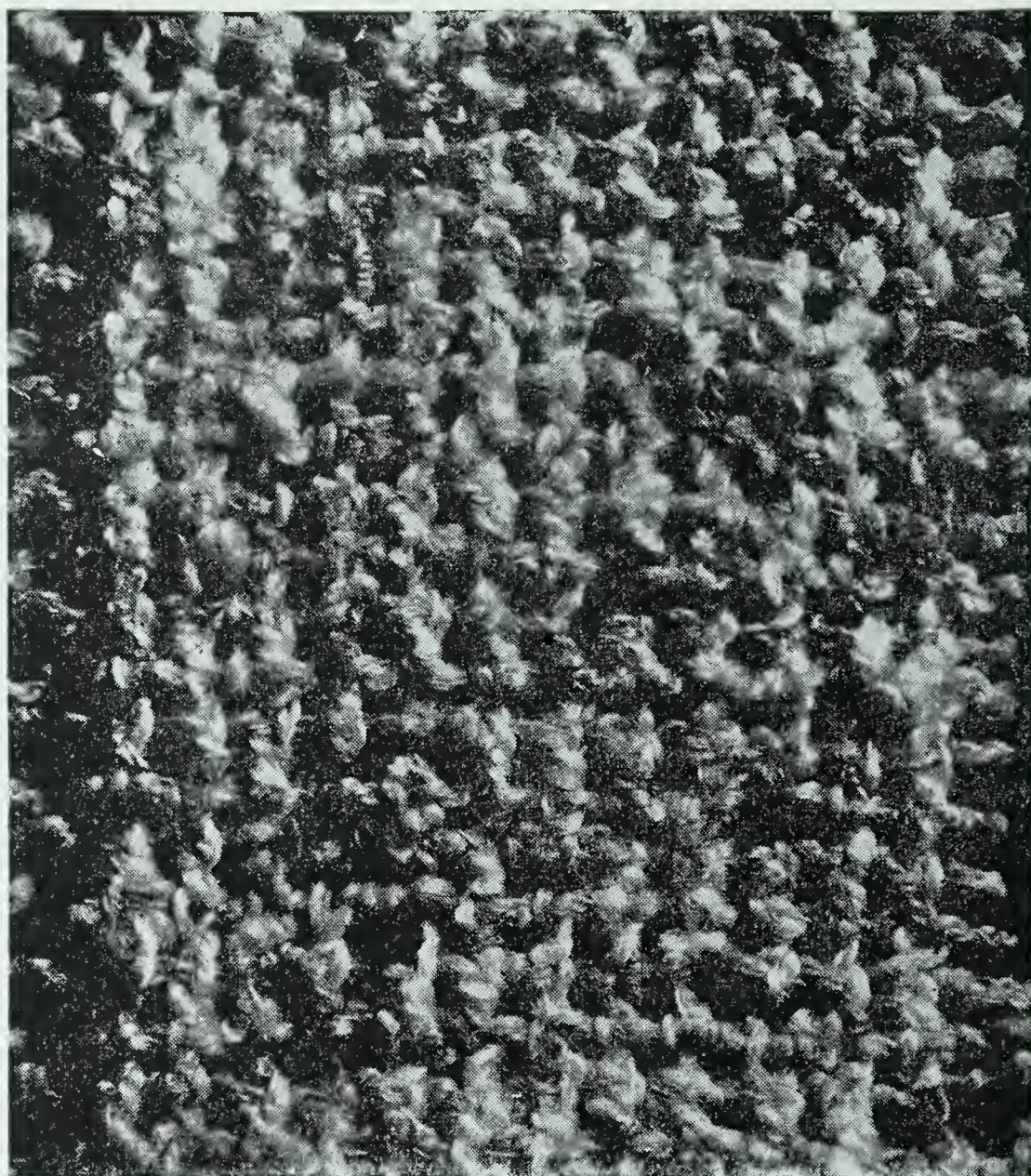


Ply yarns and grouping combined to create design.

ever, complex yarns are usually constructed from two or more single yarns that vary in some way such as fiber, color, size, ply, the amount or direction of twist, or their finish; or yarns that are alike are combined by varying the tension or speed of delivery, allowing one part to loop upon or twist around the other. Various fibers may be combined in a yarn for a special purpose. Cotton or rayon may be blended with or covered by wool or silk in an effort to lower the production cost, or two types of rayon may be blended to obtain some desired effect. These should not be classed as complex yarns, although they are made of more than one kind of fiber, because they do not impart an unusual or rough appearance to the cloth.

Most complex yarns consist of at least two parts: the foundation yarn, known as the base or core; and the effect yarn, which is wound around or looped upon this. Often a third part or tie yarn is necessary to fasten the effect yarn to the base.

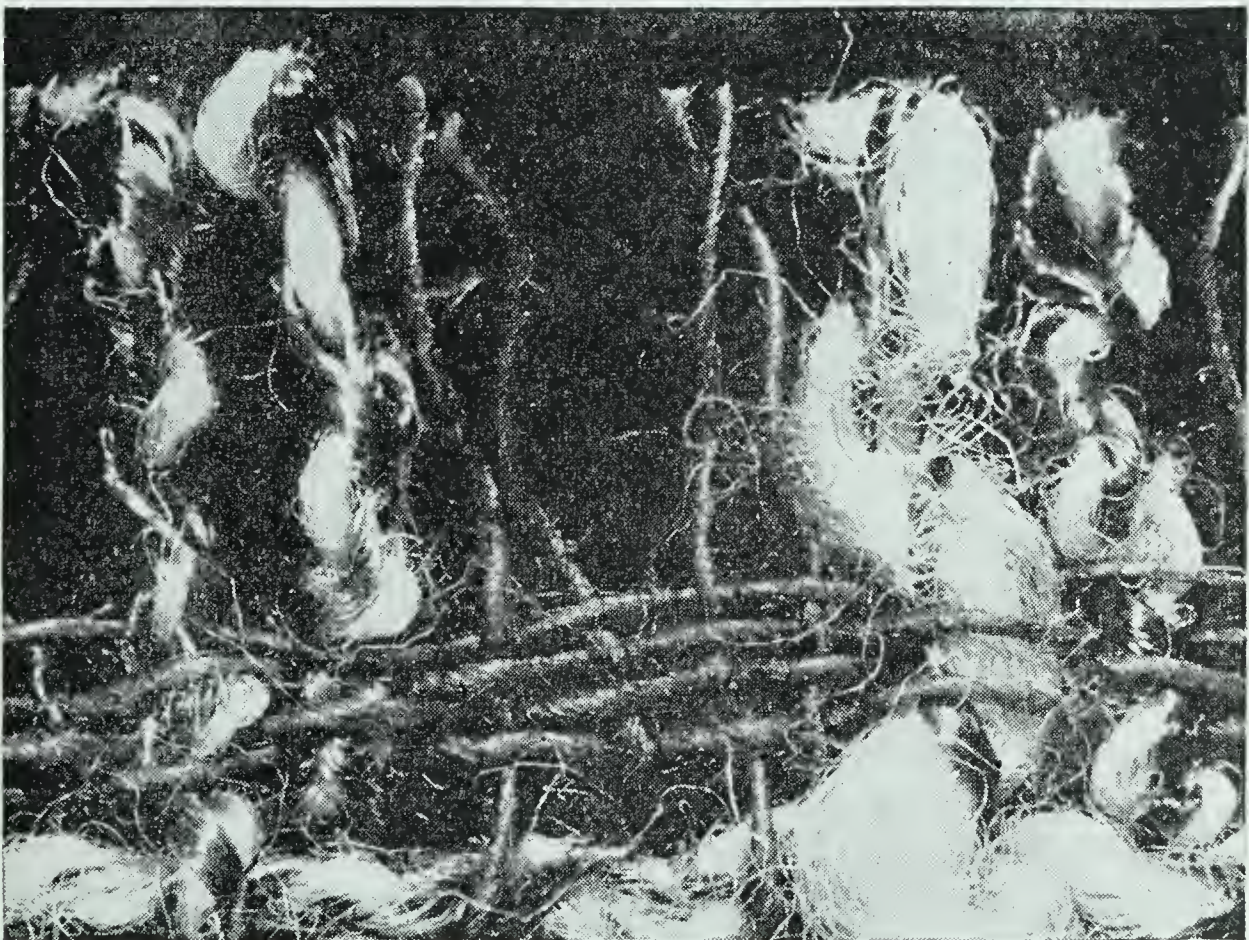
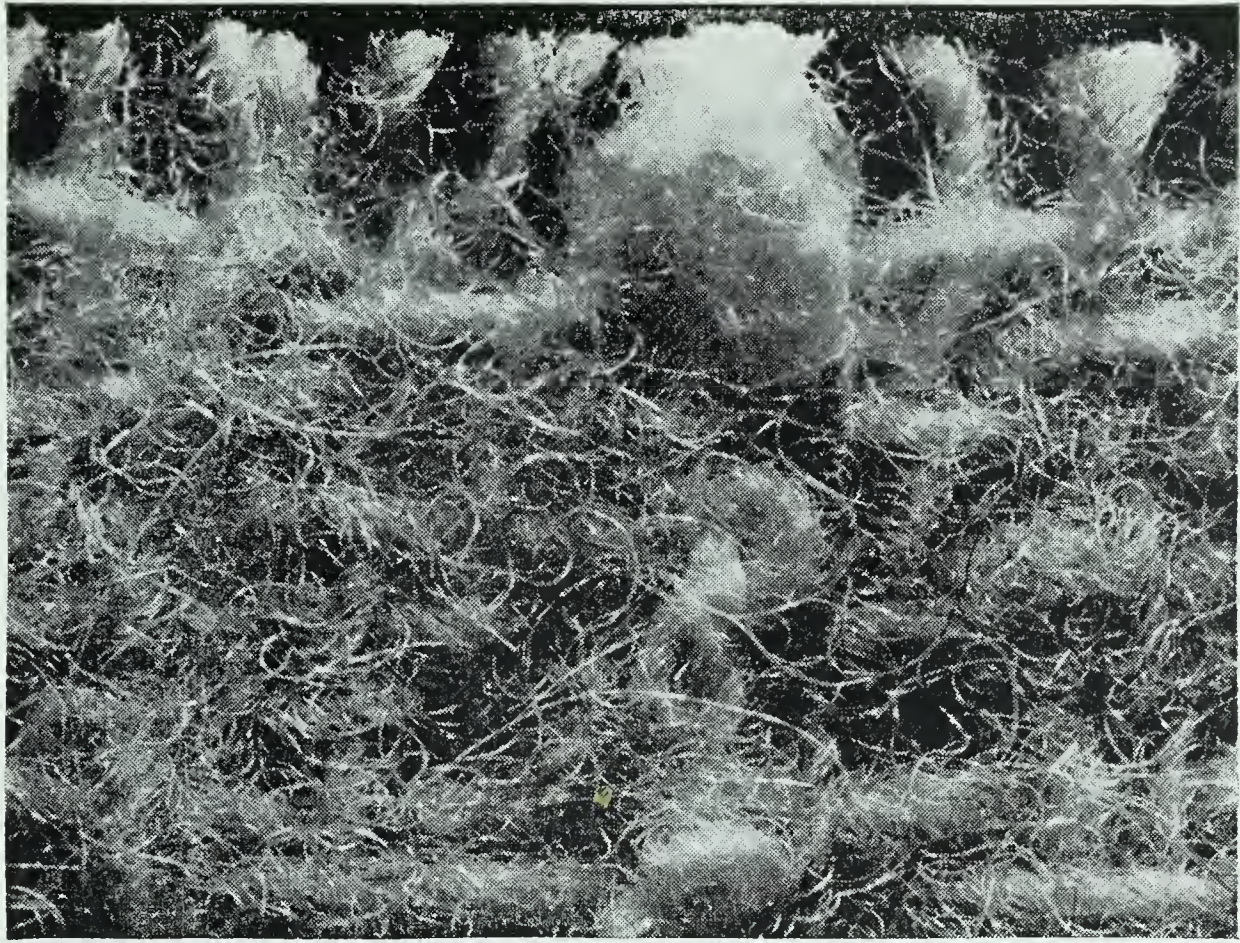
A slub yarn in which soft untwisted places are formed at



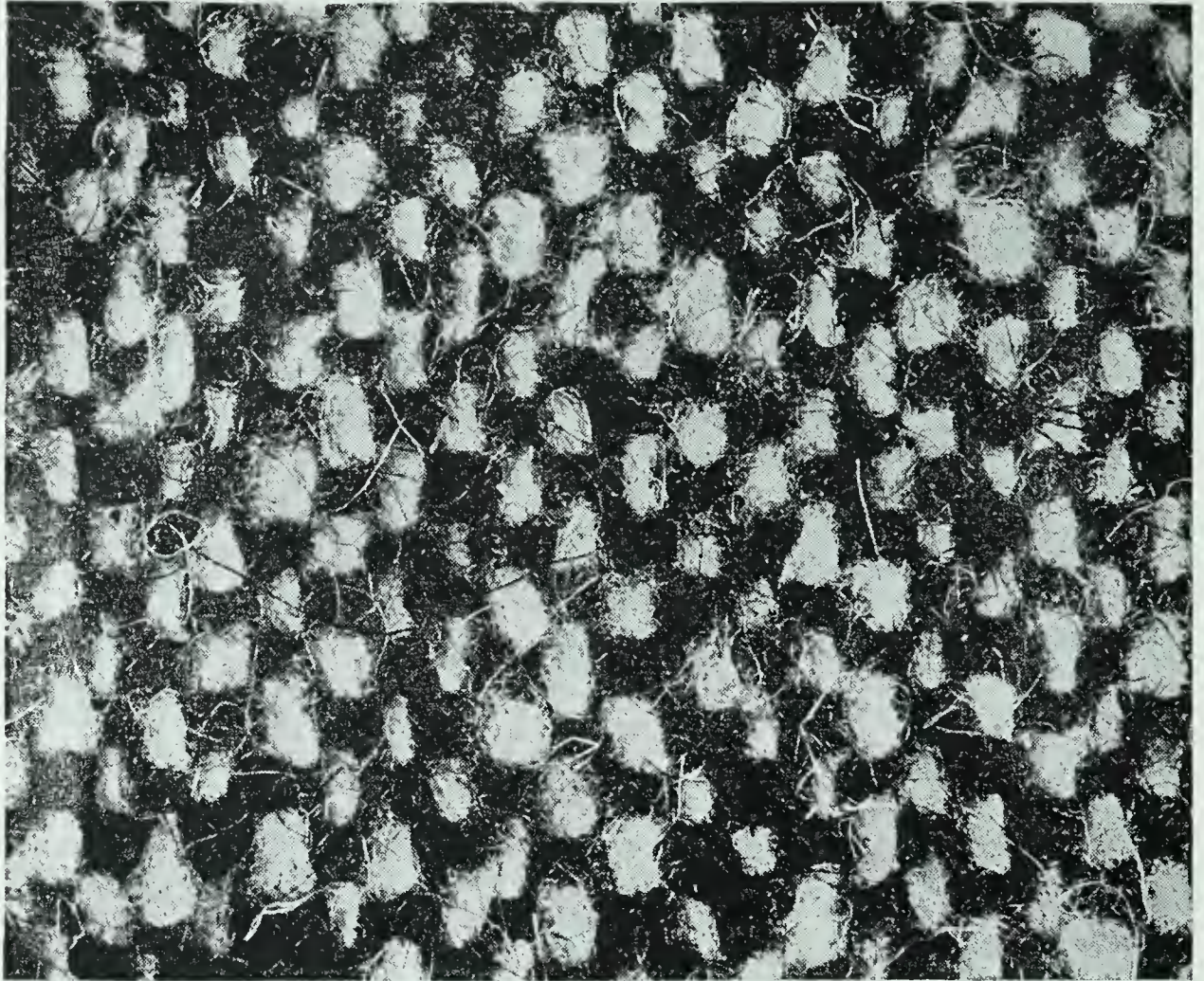
A type of ratiné. Gimp yarns are used in this gauze-woven material.

frequent intervals may be a single-strand yarn, as the one shown on page 86, or it may consist of two or more such strands.

The corkscrew is a complex yarn in which the desired effect is obtained by twisting together yarns of different diameters or by varying the rate of speed or the direction of the twist. It is often produced by twisting a coarse two-ply yarn with a fine single. The coarse yarn, being given out faster, wraps around the fine one. A yarn in which one or more effect yarns is thus wound around a base is sometimes known as a spiral.



Top, a small loop is formed on the surface of this fabric by the use of complex yarns. Bottom, complex yarns constructed from two brown and two white strands are combined with fine simple yarns in this novelty fabric.



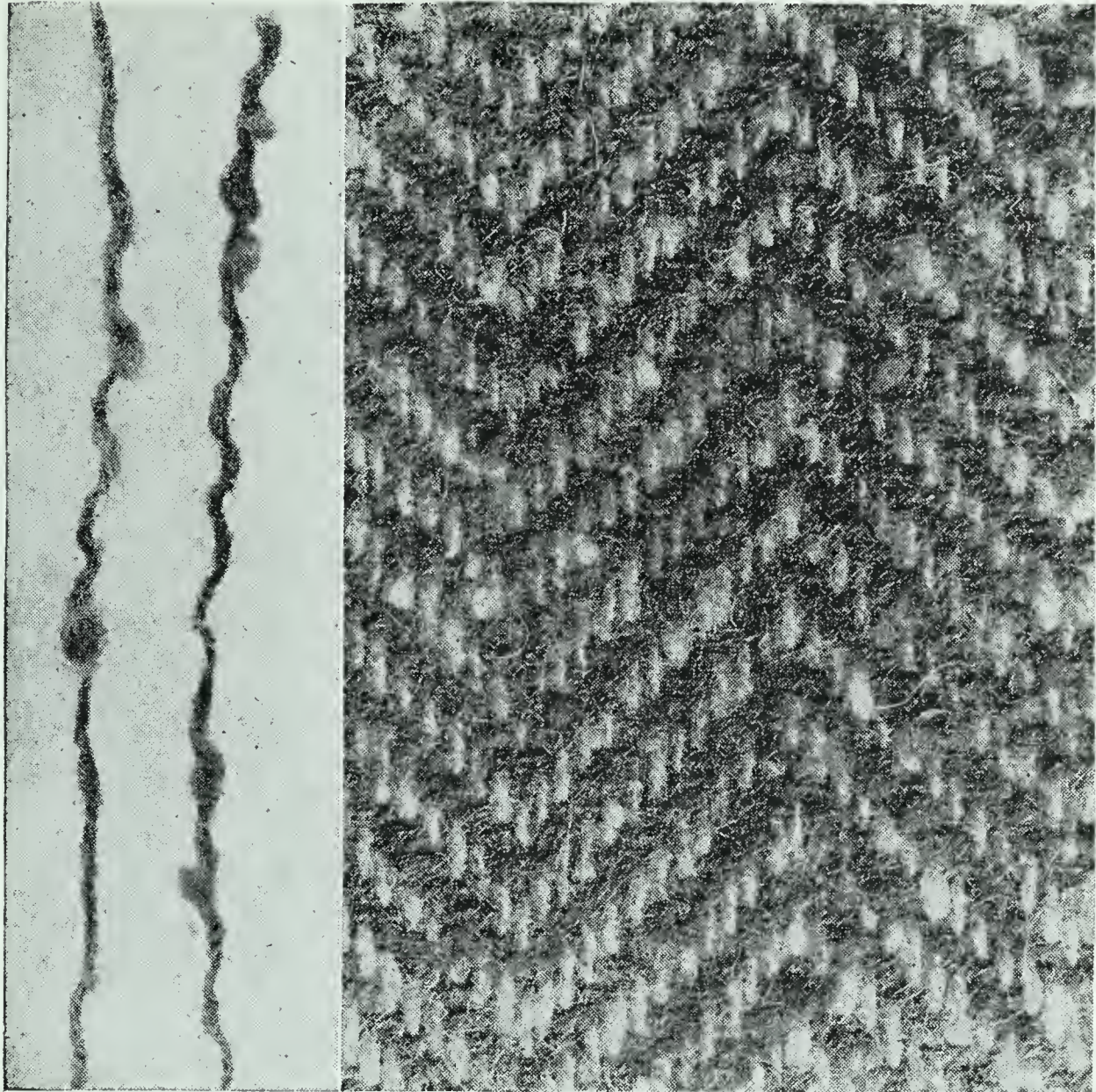
Tweed, a fabric showing use of complex yarn.

This type is not usually found in dress fabrics but is often used in the construction of a covert cloth.

Gimp yarns, used in ratiné and similar fabrics, are those in which an effect yarn is twisted around a base with a difference in the speed of delivery of the two, and to this a fine tie or binding yarn is added. (See page 86.) This addition requires a second twisting that is done in the direction opposite to that of the first. Various fabrics designed largely for clothing uses, constructed of this type of novelty yarn, may be found on the market at different times. They are made of cotton, wool, or rayon, or a combination of these.

Knot or spot yarn is one in which a spot is formed at regular intervals by means of additional turns of the effect yarn around the base at these places. (See page 86, bottom.)

Knot, spot, or slub yarns, in their variations, are found in



Textural effect produced with single-strand yarns into which bunches of colored fibers have been twisted. These spots tend to wear off.

one of the many types of tweeds that are always more or less popular. (See the illustration on page 92.)

Loop yarn consists of one or more fine singles in the form of loops on a coarser foundation. The difference in the speed of delivery of these effect yarns and the base determines the size of the loop. A fine tie is added during the second twisting. Many variations of the above groups of complex yarns may be found in the novelty fabrics popular at different times.

Flock yarn consists of a single strand to which loose fibers are applied at intervals and are caught and held by the twist.

This type of yarn is often used in tweeds but the fabric is not recommended as the color may wear off. (See page 93.)

Suggestions for the Laboratory

Study standard fabrics of different textures to determine how a variation in the size and twist of the yarns has influenced the properties of the cloth.

Study fabrics constructed from complex yarns. How do the different types of complex yarns influence the texture and service qualities of the cloth? Compare tweeds made of knot, spot, or slub yarns with those made of flock yarns.

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Unit Three

HOW PROCESSING ALTERS AND REFINES CLOTH

PROCESSING, which includes all treatments given to the fabric after it has been constructed, may be classified as *general processes* and *surface processes*, *dyeing*, and *special* or *service finishes*. Dyeing and special finishes are discussed later.

PROBLEM 1. WHY ARE FABRICS PROCESSED?

The bulk of manufactured cloth falls into three broad divisions: *gray cloths*, *converted cloths*, and *mill finished* or *colored woven cloths*. All fabrics as they come from the loom or knitting machine are unsightly and vary but little in their appearance. Many of these fabrics are woven from unbleached yarns and in this form are known as *gray* or *greige* goods. A small portion of gray goods is sold in this state, but by far the greater portion is *converted* into fabrics having special characteristics for specific uses. These are known as converted goods. Converters develop new fabrics and determine the processing best suited for each type of cloth so that the most economical and efficient use may be made of it. By processing good fabrics are made better, poor fabrics are improved, and variety is obtained.

Colored woven cloths, those constructed from colored yarns, are made ready for use by the mills weaving them. These fabrics are known as mill-finished. Gingham and chambrays are examples of mill-finished goods.

All fabrics must be inspected for defects in order to grade and evaluate them. This is also done to check on the quality



Courtesy American Woolen Co.

Inspection of fabric for defects.

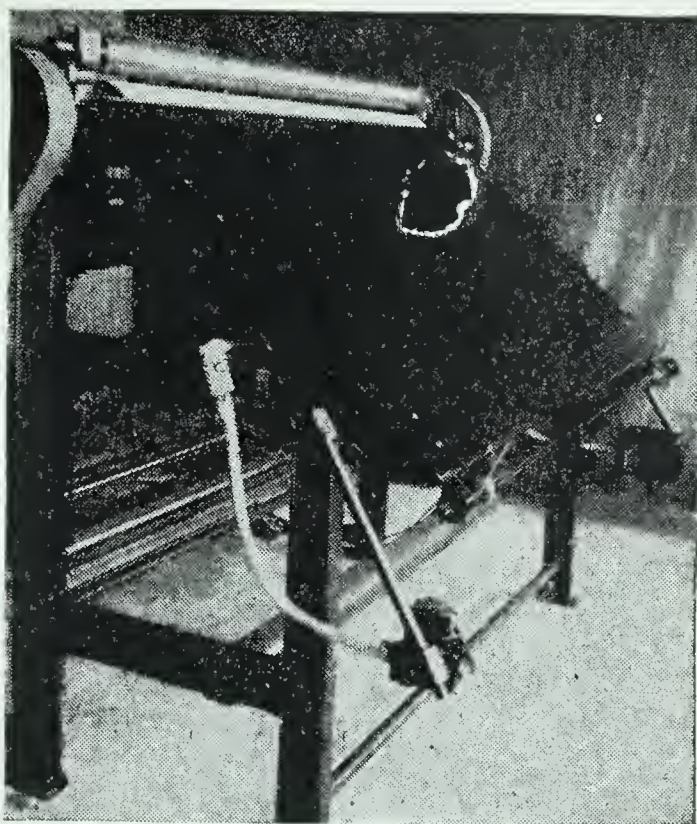
of the yarns and the efficiency of the equipment. There are always some broken yarns and thick and thin places, but many of these will result in seconds or fabrics of inferior quality.

For inspection, sometimes called *perching*, the fabric must be spread out where there is good light so that the inspector may easily locate and mark all broken ends and defective weaving. (See above.) All knots are brought to the surface

and cut off in a process known as *burling*. A *mender* weaves in or mends places that were marked by the inspector.

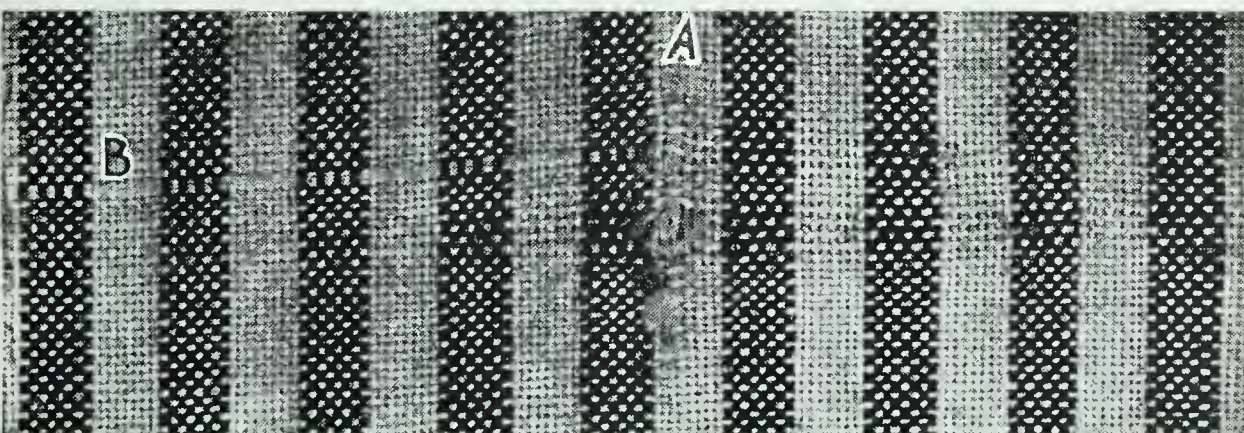
The processes given to fabrics differ somewhat, depending on the fiber and the effect desired. Many of the hidden qualities in textiles are dependent on the processes they have been through and the care with which the cloth was handled.

General processes as discussed here include those given to most fabrics for general improvement or refinement of the cloth, and surface processes are those altering only the surface of the fabric.



Courtesy Curtis and Marble Machine Co.

Inspection machine having great possibilities in the detection of fabric flaws.



From "Specifications for Fabrics to Be Rubberized," by S. G. Byam and L. R. Bailey, *Textile World*, Vol. 78 (1930), p. 188

Defects of this order may require repair. A, broken warp yarn; B, heavy filling yarn.

PROBLEM 2. HOW DO GENERAL PROCESSES ALTER THE CHARACTERISTICS OF THE CLOTH?

As a complete discussion of all textile processes would be impractical in a text of this type, only the more important processes will be discussed here. The order of their application differs according to the type of finished fabric that is desired; therefore an alphabetical order is used.

Bleaching. Fabrics may be bleached by the action of the sun's rays together with dew and frequent wetting. This, once the common mode of bleaching, is still used in the factories of Ireland for fine table linen but has been discontinued in the home except for its occasional use in bleaching muslin.

Commercially, textiles are bleached either before or after being constructed into fabrics. This is done by the action of chemicals, which may change the coloring matter of the fibers to a colorless compound or render it soluble. If the chemical action of bleaching is that of oxidation, the material will remain a permanent white; but if the action is that of reduction, exposure to light and air will tend to oxidize the material back to its natural color. Wool fabrics that are guaranteed not to turn yellow have been bleached by oxidizing agents, and the color has been permanently destroyed.

Bleaching powder $\text{Ca Cl(O Cl)4H}_2\text{O}$ is commonly used in bleaching cotton and linen. The fabric is saturated with a solution of bleaching powder and allowed to be in bins for several hours. From these bins the cloth is run in rope form through a washer, a sour, and another washer. If the goods are to remain white, blueing is added to the last wash water.

Wool, silk, and many fine fabrics have been bleached with hydrogen peroxide for many years. Since 1930 the cost of this type of bleaching has been reduced to that of bleaching powder. Scouring and bleaching may be done at the same time when using peroxide, but more satisfactory results are obtained by first scouring in a kier and running the goods through a washer into the bleaching kier. When it is necessary to bleach in open width, the peroxide process is most frequently used.

Crabbing and decating. The individual characteristics of the wool fiber necessitate the use of processes not common to other fibers. Of these, crabbing and dry and wet decating are the most important. These processes impart a permanent set to wool fabrics which is necessary because of the fulling or milling of wool which occurs in the presence of heat, moisture, and any type of agitation.

Crabbing. The purpose of crabbing is to set the warp and filling yarns at right angles. This is accomplished through removing all strains by passing the goods in full width through hot water. One type of crabbing machine includes a roller on which the dry cloth is wound, an expanding roller, and two troughs of hot water and one of cold water each containing a crabbing roller. Another type of machine known as the continuous type includes a series of rolls in a large vat and at the end of the vat there is a special cooling tank filled with cold water.

Wet decating. Wet decating is a setting and lustering process which is necessary to protect the nap from entanglement during dyeing. The apparatus consists of a trough, a perforated boiling roller, a vacuum pump, and a tension arrangement. The goods are wound nap side down onto the roller, which has been covered with a cotton cloth to assure even penetration of the water throughout the entire roll. Water at a temperature of from 140° F. to 180° F. is circulated through the roller in both directions for from 10 to 20 minutes, or steam is blown from the inside of the roller for five to ten minutes. The vacuum pump is then used to pull either cold air or cold water through the cloth to cool it.

Dry decating. Dry decating is used to set the luster obtained through pressing or calendering. The cloth is wound onto a perforated roll together with a fine-faced cotton leader. A heavy leader cloth is wound on top of the roll or cloth. The cloth roll is placed in a preheated boiler which is sealed airtight, and a vacuum is then created in the boiler. Steam enters the boiler through the perforated roll, thus being forced through the cloth. After two or three minutes, steam enters the boiler and forces its way through the cloth from the out-

side of the roll. This process serves also to set the fabric in length and width.

Mercerizing. Mercerizing is a treatment given to cotton to increase the luster and strength and make it more reactive to dyes. The cotton fiber is cylindrical as it grows, but when the boll opens and the plant juices dry up the fiber flattens and becomes twisted. Mercerization consists of immersing the fiber in a caustic soda solution which causes the fiber to swell, thus becoming cylindrical and straight. Details of this process are given later.

Scouring and kier boiling. Any fabric becomes more or less soiled during the process of construction, and it is necessary to wash or scour it before it can be given any other treatments in preparation for the market.

Desizing, the removal of sizing or slashing material added to the yarns before weaving, is done at this time. Rayon requires the minimum amount of scouring, but a special scouring spoken of as *kier boiling* is necessary to remove the natural wax from cotton and linen. The pressure kier boil is the most common method of boiling out cotton preparatory to bleaching. The kier boiler holds from 2,000 to 10,000 pounds and is furnished with a spray pipe by means of which the kier liquor is forced by steam pressure and sprayed onto the goods. The kier liquors are generally made up of one or more alkalis. Most bleacheries have automatic pilers which uniformly pack the cloth by means of a stream of water. The length of time required to kier boil will vary from two hours to as much as 14 hours, depending on the strength of the solution, the temperature, and the type of goods and desired effect.

The weight of the goods being processed often causes permanent creases known as crow's feet. To prevent this, heavy fabrics are often boiled off in open width in a tank. This type of apparatus has never been standardized, but some means is provided which keeps the cloth moving through the liquor in the tank.

Shearing. Shearing is a mechanical process which consists of cutting or trimming the fiber ends on the surface. This is used on all cloth except that with an extremely heavy nap

such as blankets and similar cloths. One of the early processes, that of singeing, cleans the surface of the cloth, but fiber ends are raised during wet processing which can be removed only by shearing. Singeing done at this time would affect the handle of the cloth and cause an odor which could be removed only by another wet process. For pile fabrics shearing is used to even or level the pile and for raised fabrics to even the nap. In shearing, which is a continuous operation, the ends of the piece are sewed together so that the cloth runs through the machine in an endless band over bars, guide rollers, and brushes. An average speed of operation is 8 to 10 yards per minute. The setting of the cutting device is higher at the first cutting and is gradually lowered to the desired point at the final cutting. This is done to prevent tearing of the fabric by the removal of immense amounts of fibers all at once. The most severe shearing is done on fabrics which require a clear finish, such as gabardines and serges. Napped fabrics are sheared the amount necessary to obtain the length of nap desired.

Shrinking. Textile materials are under constant strain from the time they enter the yarn manufacturing plant, through fabric construction and many of the processing treatments. When the fabric is wet and agitated as during laundering and in some types of dry cleaning, this strain is released and the fabric undergoes what is known as shrinkage unless some previous treatment has been given to prevent this. Shrinkage is not determined by the kind of soap or the temperature of the water used. Firm, closely constructed fabrics have less tendency to shrink than loose open-mesh material; however, unless given some type of shrinking treatment, they will draw up when wet. The amount of shrinkage will vary with the type of fiber. Cotton and linen usually shrink when wet, and wool will always draw up due to its felting property unless chemically treated to prevent this. Controlled shrinking is one of the service or special finishes that cannot be judged by the purchaser and therefore must be indicated by a label giving the amount of residual shrinkage that remains. Details of this subject will be discussed later.

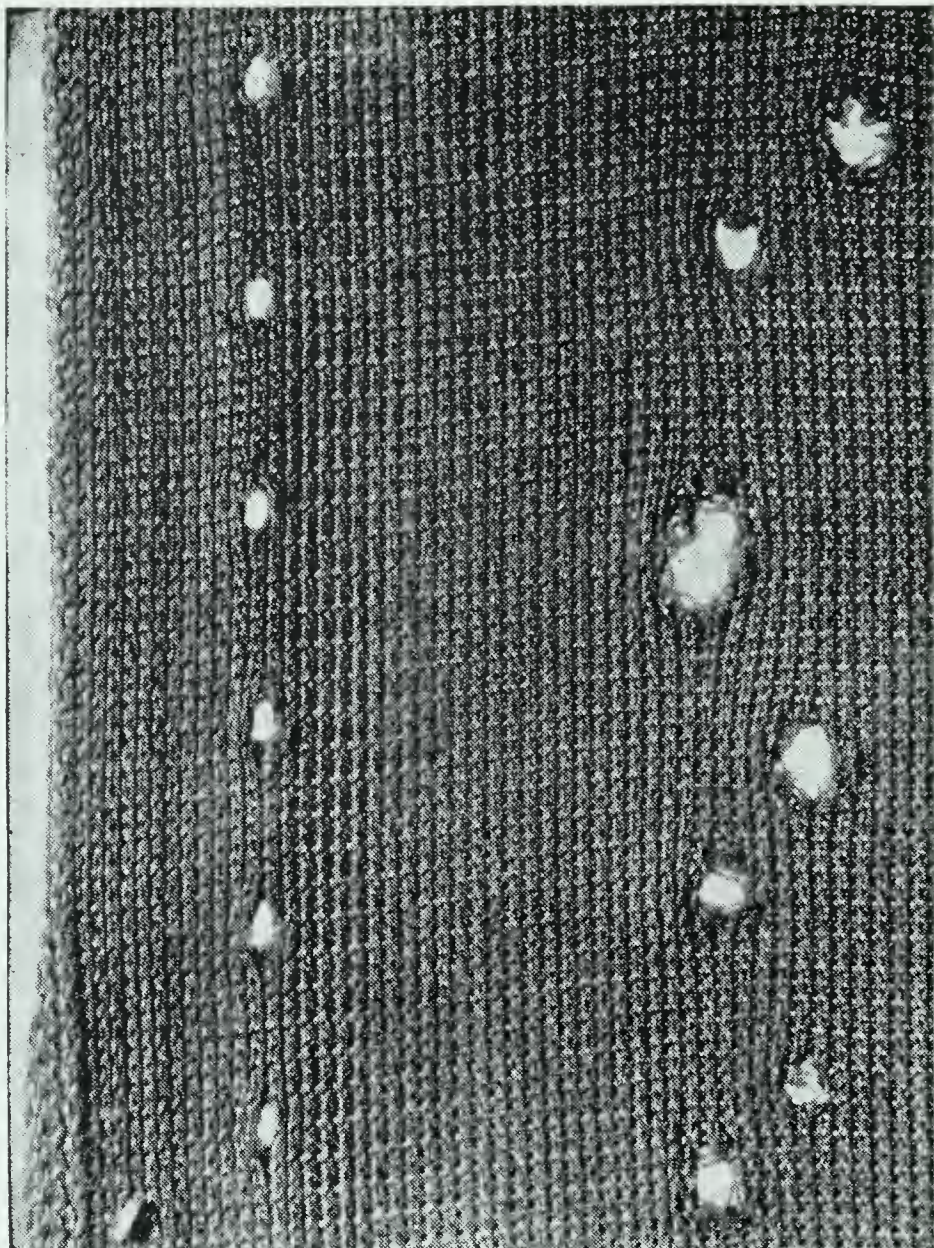


Illustration of damage done to knitted fabric during tentering.

Singeing. Singeing, the removal of fiber ends by passing the fabric over a flame or across a hot plate, is a process used on cotton, wool, and spun rayon fabrics that are to be given a smooth finish. The cloth must be prepared for singeing by brushing and shearing. This process removes dust and lint as well as loops and hanging ends. The plate singer is the oldest type, and the most modern singer is an open gas flame. On entering the singer the fabric passes over tension bars which prevent wrinkles and curled selvages. Plate and roller singers run from 150 to 250 yards per minute and gas singers may run as high as 300 yards per minute. After passing over the

SUMMARY OF GENERAL PROCESSES DISCUSSED IN THIS UNIT

NAME OF PROCESS	HOW IT ALTERS THE FABRIC	APPLIED TO
Bleaching	Whitens the cloth	All fibers
Crabbing	Sets warp and filling	Wool only
Decating, dry and wet	Sets nap and adds luster	Wool only
Mercerizing	Increases luster, strength, and absorbency	Cotton only
Scouring and kier boiling	Removes waxes, oils, and sizing	Cotton and linen
Shearing	Clips ends of fibers	Cotton and wool
Shrinking and fulling	Releases strains and shrinks somewhat	All fibers
Singeing	Removes loose yarns and fiber ends	Cotton, wool, and spun rayon
Sizing and weighting	Increases weight and gives body	Cotton, some ray- ons and silk
Tentering	Straightens and sets warp and filling at right angles	All fibers

singeing apparatus the fabric goes into a water box which frequently contains a small amount of sulfuric acid.

Sizing and weighting. Until recently, the finishing of cotton goods consisted chiefly of coating the surface with a starch paste and calendering it. This corresponds to the home practice of starching and ironing cottons. Starches, British gums, and dextrans are used as thickening agents. To these a softening agent such as tallow, oil, or wax must be added. If it is desired to add weight to the fabric, such a substance as talc, China clay, or French chalk is also added.

The high cost of the silk fiber and the fact that much weight is lost when the silk gum is removed in processing, together with the fiber's peculiar physical and chemical characteristics, all contribute to the practice of *metal weighting* to give body and stiffness to certain types of silk fabrics. A description of this process is given on page 256 in Unit III, Section II.

Tentering. Tentering is necessary for all fabrics in order to straighten and set the cloth a desired width and length. In the process of tentering the fabric is stretched more or less in both the width and length. Either a clip or pin tenter frame is used for this purpose. If the fabric is such that a clip might injure it, the pin tenter should be used. (See page 102.) The sides of the cloth are caught by clips or pins, and as the dampened cloth moves forward the frame gradually widens so that the cloth is stretched. The distance between the traveling chains can be adjusted in order to stretch the fabric to any predetermined width and the length of the fabric can be adjusted as desired. The placing of warp and filling yarns at right angles is important in woven fabrics. The dimensions of the cloth are not permanently set in tentering and excessive stretching during this process will result in excessive shrinkage during laundering. Then the fabric will revert to its original size unless controlled shrinkage treatment is given.

PROBLEM 3. HOW DO SURFACE PROCESSES ALTER THE CLOTH?

The appearance of the cloth may have been influenced by the general processes through which it has passed, but other changes are made by surface processes which alter it in one or more ways.

Beetling. Beetling is a treatment given to linen to soften the fabric and give it luster. In beetling, the cloth is rolled onto a wooden roller which revolves while a series of wooden hammers beat the cloth. This is continued for from 20 minutes to one hour, depending upon the weight of the cloth. A second rolling and beating may be required to obtain the desired soft, full, thready feel. This treatment softens the linen

fabric and flattens the yarns. Cotton fabrics are sometimes beetled to give them a linenlike appearance.

Calendering. Calendering, which corresponds to ironing, gives the final smoothness to the cloth. All calenders consist of from three to eleven heavy rollers. In general practice these rollers are alternately a soft and a hard surface roller. Pressure may be maintained by means of weights on a lever arm or by hydraulics. The diameter of the calender rolls is never less than eight inches and may be as much as 12 or 15 inches.

Various effects are produced dependent upon the amount and type of starch used and the manner in which the fabric is run through the calender. The heat, pressure applied, and rate at which the fabric passes between the rollers and the number of times the cloth passes through the calender are determined by the effect desired.

A highly glazed cloth is produced by means of a friction calender. In this the cloth is passed through the calender at a speed lower than the highly polished roller revolving against it. This serves to polish the cloth.

Embossing and schreinerling. Embossing and schreinerling are done by means of a two- or three-roll type of calender. In the two-roll type the upper roller is a steel engraved roll which operates against a roller of paper or cotton. Any type of design may be engraved on the steel roller. The cotton roll is dampened with soap and water, and the heated engraved roller is run against it with sufficient pressure to impress the design into the cotton roll. When the fabric is passed between the two rolls the design is impressed on the fabric.

Moiré finishing. Moiré is a finishing process which produces a high luster and characteristic lines or shadows which give a definite pattern to the cloth. This finish is accomplished by laying two identical fabrics with the right sides together and applying heat and pressure to them. A hot calender serves this purpose. If the ribs of the fabrics are laid parallel, the pressure will force the threads of one cloth into the recesses of the other, resulting in a brilliant luster on both pieces. If, however, the filling yarns are not parallel but are allowed to cross each other, the action of the calender will cause the

yarns to flatten at the points where they cross. The flattening of the yarns in certain areas results in the pattern.

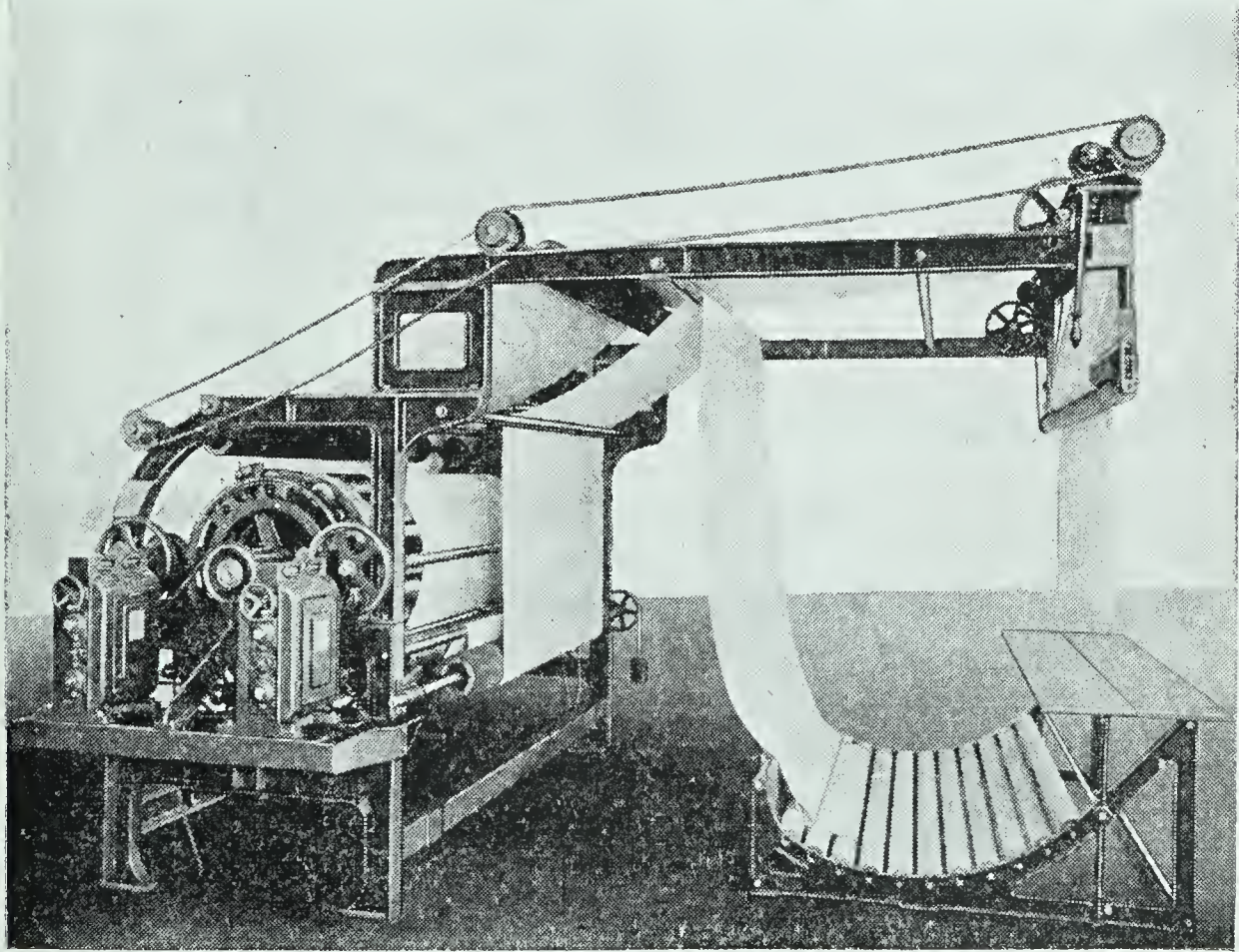
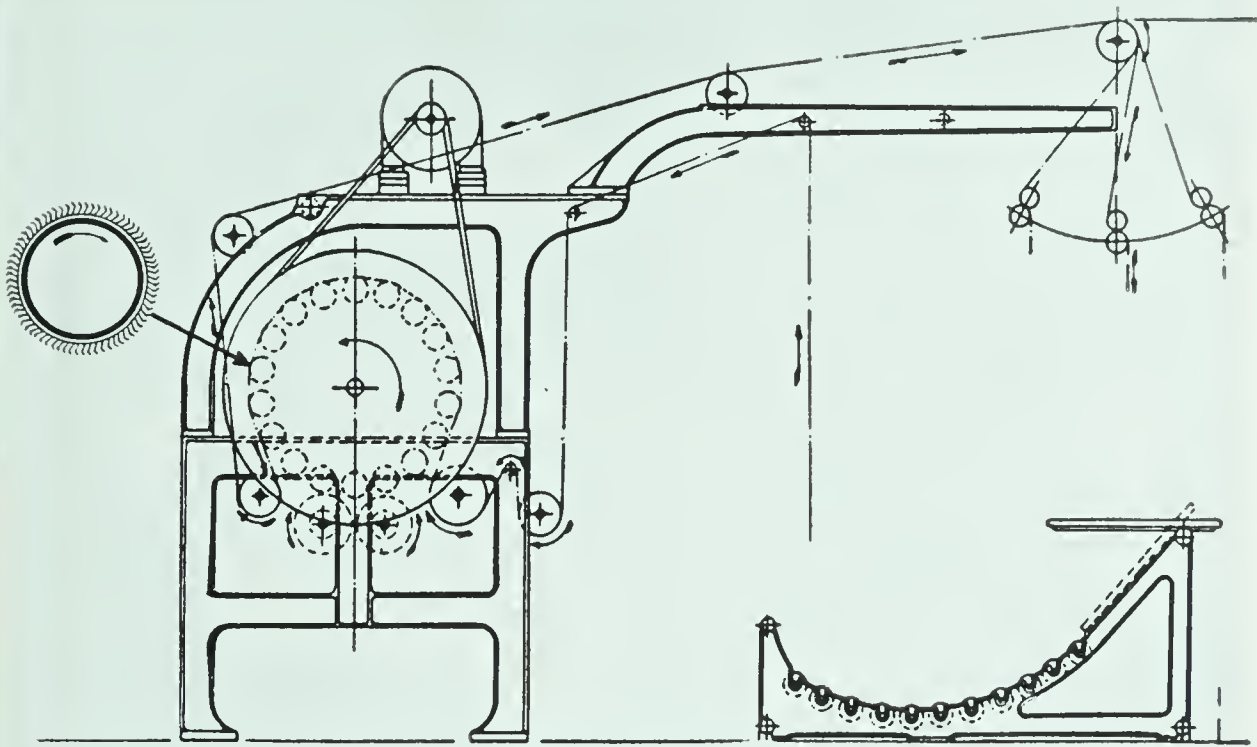
Several different methods are employed to produce the *moiré* pattern. In the Pekin method the goods are retarded at certain points while being run double on a beam. This operation, known as "tracing," produces a pattern of lines running warp-wise. In the Scratch method such patterns as tear drops, flowers, palms, or animals may be produced. The fabric is doubled and run through the scratching machine, which resembles a crude roller printing machine in which the roller is made of rubber. A number of scratch blades, set in a roller, revolving at a high speed, bear against the engraved rubber roller. At the points of contact of the scratch blades and the engraving, the filling yarns of the doubled fabric are shifted.

Other styles require special equipment and specially constructed fabrics for their production. (See page 158.)

Raising operations. Raising operations consist of lifting fiber ends from the body of the fabric to form a nap or covering on the surface of the cloth. The nap is produced to give a sponginess or lofty handle to the goods or to conceal the weave or design so as to soften the outline and blend colors. The raising operation is accomplished by gigging or napping.

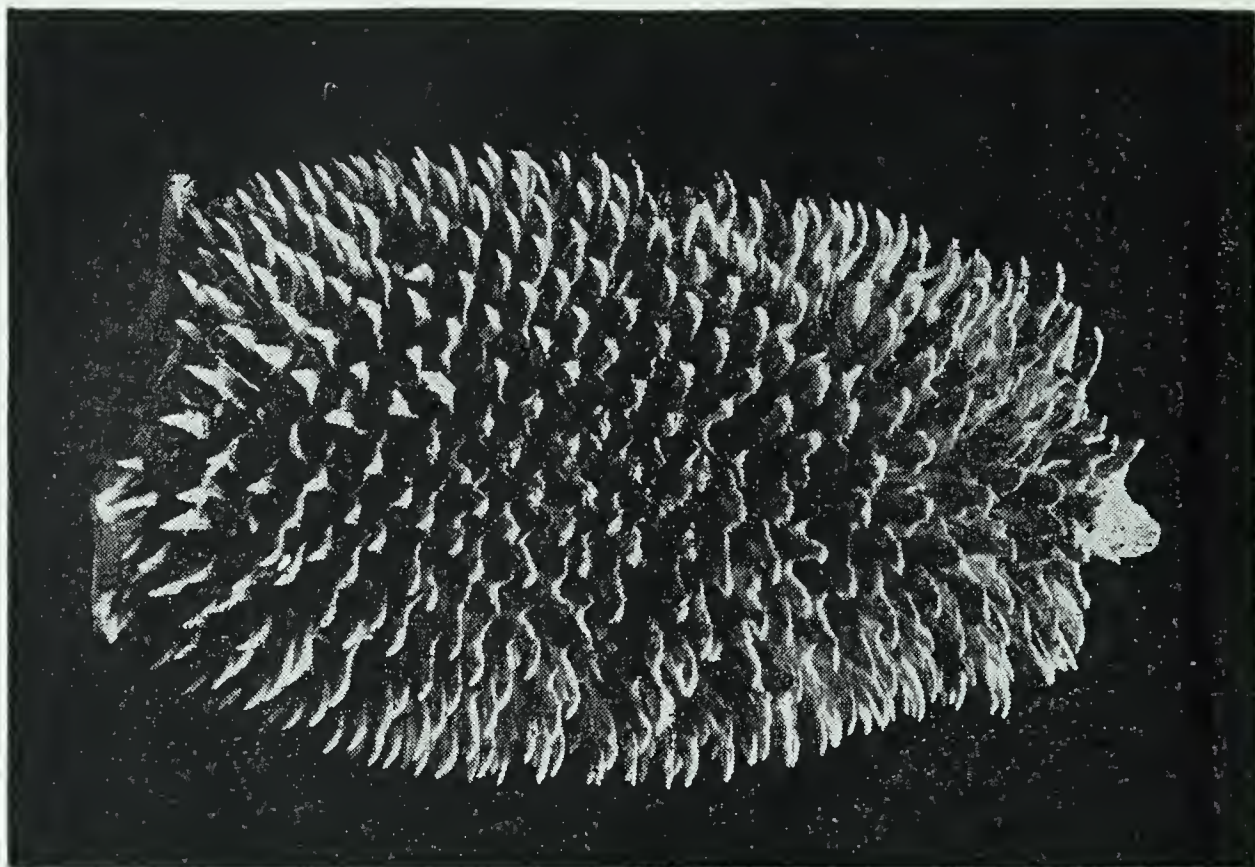
Gigging. Gigging is done in the moist and wet state by means of vegetable teasels. The fiber ends are raised when the fabric is moist as a process preliminary to wet gigging. The purpose of wet gigging is to lay the fibers in one direction on the surface of the cloth. Vegetable burrs known as teasels are used for this purpose. (See page 108.) The teasels are fastened into iron slats mounted on a drum which revolves at a higher speed than the cloth coming into contact with it.

Napping. In napping, the fabric is passed over a revolving cylinder covered with short, fine, bent wires that scratch the ends of fibers to the surface. (See page 107.) In general, napping would be accomplished if the linear speed of the cloth as it is carried around by the main cylinder were either greater or less than the linear speed of the napping cylinders. If the surface of the napping roll runs slower than the cloth, the nap will extend backward; if the surface of the napping roll runs



Courtesy David Gessner Co.

A modern double-action napping machine. In the diagram a cross section of the napping roll is shown.

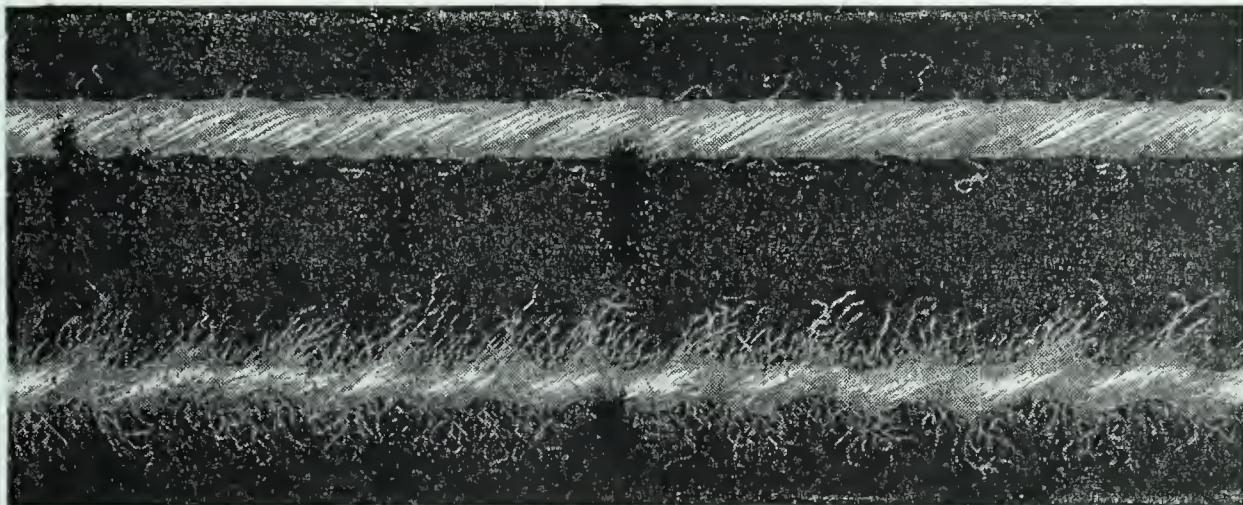


Vegetable teasel used in the raising operations.

faster than the cloth, the nap will extend forward. As the whole unit revolves, these separate actions take place at alternate rolls.

SUMMARY OF IMPORTANT SURFACE PROCESSES

NAME OF PROCESS	WHAT IT DOES	APPLIED TO
Beetling	Softens and adds luster	Linen and cotton
Calendering	Smooths and adds luster	Cotton, linen, and rayon
Embossing and Schreineriing	Adds luster and design	All fabrics
Moiréing	Produces a patterned effect	All except wool
Raising (gigging and napping)	Lifts fiber ends to form nap	Cotton, wool, and spun rayon



Courtesy Kenwood Wool Products Co.

Yarn before and after napping.

Suggestions for the Laboratory

Select and mount specimens of various fabrics that could be produced from unbleached muslin by a variation in the processing. Illustrate bleaching, sizing, and mercerizing.

Compare weighted silk with raw silk and unweighted silk; wool flannel with broadcloth and serge; unmercerized cotton with mercerized cotton; and cotton damask with linen damask.

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Unit Four

HOW DYES ARE APPLIED TO TEXTILES

THE first records of man show that he was familiar with the use of dyes to give emphasis and interest to his surroundings. From these early beginnings when man used only substances provided by nature, the dye industry has developed to one of great economic value. Although, according to Webster, color is a sensation evoked as a response to the stimulation of the eye and its attached nervous mechanism by radiant energy of certain wave lengths and intensities, common usage has for so long considered color as a part of the object itself that it seems impractical to discuss color as separated from the object emitting this stimulus.

Dye, through which the sensation of color is evoked, is recognized as a compound that can be fixed on a substance with more or less permanence in the form of a color. This, the common use of the term color, is accepted here.

PROBLEM 1. WHAT IS THE RELATION OF LIGHT TO COLOR?

A discussion of color must start with an explanation of light because without light there can be no color.

Light, or radiant energy, is composed of electromagnetic rays. These rays range in length through those that furnish heat, those that furnish visible light, and those classed as ultra-violet, X-rays, and gamma rays. The following table shows the relationship of the length of these rays:

KIND OF RADIATION	MILLIMICRON	CENTIMETERS
Gamma rays.....	.01	0.000000001
X-rays.....	.1	0.00000001
Shortest ultraviolet.....	60.	0.000006
Transmitted by quartz.....	200.	0.00002
Shortest solar waves that can pass through at- mosphere.....	300.	0.00003
Shortest visible rays.....	370.	0.000037
Maximum chemical effect (solar radiation).....	400.	0.00004
Violet.....	400.	0.00004
Blue.....	460.	0.000046
Green.....	520.	0.000052
Yellow.....	560.	0.000056
Orange.....	600.	0.00006
Red.....	670.	0.000067
Red (longest visible waves).....	760.	0.000076
Limit of solar spectrum.....	5300.	0.00053
Longest heat waves.....	314000.	0.0314
Shortest Hertz waves.....	2000000.	0.2
Hertz waves in practical (wireless).....	100 to 10,000 meters	

As will be seen from the above table, the length of these rays varies over a long range. The gamma rays are so short that one hundred billion would not measure one-quarter of an inch and the longest, the Hertz waves, useful in wireless telegraphy, are six-tenths of a mile in length. Although these rays differ so widely in wave length, they all travel with an equal velocity of 186,000 miles per second. If the waves ranging in length of from 400 to 760 millimicrons are allowed to fall upon a transparent object, they will pass through it. If a beam of white light is allowed to fall upon an opaque object, it may be reflected almost totally, or it may be completely absorbed. In other instances some of the rays are reflected and others are absorbed.

According to some scientists, bodies that reflect all the rays of the spectrum in their proper proportions are white; those that reflect none of the rays are black. Other bodies exhibit a selectivity, reflecting only rays of certain wave length, the color reflected being the complement of the rays absorbed. As the length of the absorbed rays increases, the color deepens.

Colors are arranged according to their effect on the eye: by the absorption of red, green is transmitted or reflected; and

by the absorption of orange, blue is transmitted. According to this, a new order of color values has been suggested in which yellow, the shallowest color, results from the absorption of violet or the shortest rays of the visible spectrum. Rays increase in length and colors increase in depth, as shown:

RAY'S ABSORBED	VISIBLE COLOR
Violet.....	Yellow
Blue.....	Orange
Green.....	Red
Yellow.....	Violet
Orange.....	Blue
Red.....	Green

How structure of molecule affects color. Some scientists believe that an important relationship exists between the production of color and the structure of the molecule. As you will recall, molecules are made up of elements. An atom is the smallest particle of any chemical element that can exist by itself and still retain the properties of the element. Every atom consists of a nucleus surrounded by a comparatively empty region in which one or more electrons move about the nucleus somewhat as planets move about the sun. The nucleus is composed of one or more protons and generally one or more neutrons. The proton has a positive electrical charge, the electron has a negative charge equal in strength to the proton, and a neutron has no charge. There is one electron in the outer orbit for each proton in the nucleus, as the positive charge of the proton must balance the negative charge of the electron. The high speed with which the electrons move keeps them out in their circular orbit.

The properties of the elements, aside from their mass, are dependent upon the number and arrangement of electrons in the outermost orbit. The most generally accepted theory of color assumes that electrons vibrating within the molecule absorb light waves of the same frequency. The unabsorbed rays that are reflected produce the sensation of color. When electrons have higher frequencies than light waves of the visible

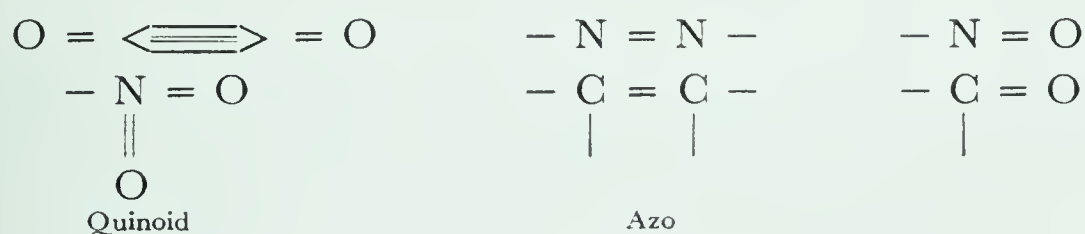
spectrum, no absorption is apparent. Under such conditions the compound is colorless.

It is thought by some investigators that the effect of the close proximity of oxidizing and reducing components within the molecule is to decrease the frequency of the electrons so that the frequency becomes that of the light rays of the visible spectrum. The absorption of these rays results in color. As the frequency of the electron decreases, the wave length increases and the color deepens.

What is meant by oxidizing and reducing components? Oxidizing components are those parts of a compound which may take up electrons from the other parts of the compound. Reducing components are those parts of a compound which are capable of giving electrons to other parts of the compound. Oxidation or reduction that takes place within the molecule is then the result of a shifting of electrons from one part to another.

A substance which contains the color-giving group is called a chromogen. The color-giving group itself within the chromogen is known as the chromophore group.

The chromophore group contains doubly bound atoms, such as:



By the process of oxidation or reduction these double bonds may shift and the chromophore groups thus be built up or destroyed. Bleaching is the process of the destruction either permanently or temporarily of the chromophore group. The presence, then, of a chromophore group gives color to a compound, but in order to fix the color in a substance the presence of such radicals as OH, NH₂, NHR, or NR₂ is necessary. These radicals are called auxochromes or color-fixing groups. They may unite with acids or bases to form salts, or they may

enter into direct combination with animal fibers which are amphoteric (both acid and basic) in nature.

PROBLEM 2. WHAT SUBSTANCES ARE USED TO DYE TEXTILES?

By the term dye we mean any compound which can, with some degree of permanence, be fixed upon a textile fiber as a color. Substances commonly used as dyes may be classified according to origin as *natural* or *synthetic*. The natural dyes are divided according to source into vegetable, animal, and mineral dyes.

Natural Dyes

The use of dyestuffs antedates the beginnings of any written history of man. In early times the plant world furnished the principal source of the dyestuffs by which man secured color. The part of the plant used varied widely. Roots, stalks, foliage, bark, berries, and seeds all were employed to some extent. Certain insects and shellfish were color sources from the animal world. Waters from mineral springs of various sorts were also utilized, though they made cloth harsh and tended to weaken the fiber.

Of the great number of dyes used in the homes and home industries of early times, some were carefully preserved as family secrets to be passed from one generation to another; others were commonly known and used. From the entire list, early records show that the vegetable dyes, indigo, alizarin, and logwood, and the animal dyes, cochineal and Tyrian purple, have played an important part in the commerce of the time.

Vegetable dyes. The early use of *indigo* in widely dispersed areas is shown by the fact that fabrics dyed with it have been removed from the tombs of Egyptian mummies over 4,000 years old, and from the graves of the Incas in Peru. Indigo is produced by the fermentative steeping of the stems and foliage of certain plants belonging to the *Indigofera* family. These plants were widely grown in India at an early date. A

period of competition with woad, a vegetable dye, available locally, followed the introduction of indigo into Europe in 1516. Now indigo from vegetable sources is largely supplanted by the synthetic product.

Alizarin, the dye used for Turkey-red calico, once so popular, came originally from madder grown in France, Belgium, or Turkey. This dye was prepared by grinding and extracting the dried, long, slender roots of madder. It was popular with calico printers because it could be made fast to laundering and light. Within the last half century synthetic alizarin has taken the place of the natural product.

Soon after the discovery of the Americas, the Spaniards introduced *logwood*, a vegetable dye, into Europe. It is obtained from a tree, *Haematozylon campechianum*, a native of the warmer parts of Central and South America and certain of the West Indies. The wood of this tree is usually marketed in the form of large blocks which are cut into chips, moistened in water, and allowed to stand until fermentation takes place. The extract thus produced serves as a dye.

Logwood, a black dye, has successfully competed with synthetic dyes for a longer period of time than has any other of the natural dyestuffs. Even now many dyers prefer logwood for silks, but its popularity as a cotton dye has decreased with the introduction of sulfur blacks.

Animal dyes. *Cochineal* was generally known in Mexico at an early date but remained unknown to the rest of the world until after the discovery of the Americas. This dye is obtained from the body of an insect, *coccus cacti*, which lives on a species of cactus. The female insects, which greatly outnumber the males, possess the color-producing quality. For the preparation of this dye, insects are brushed from the plant into a basket or iron dish and are killed by heat. An aqueous extract from these bodies is especially suited to the dyeing of silk and wool. It produces shades of crimson, scarlet, and orange. The use of coal-tar dyes has, however, greatly lessened the demand for cochineal.

Tyrian purple, probably the most expensive of the ancient dyes, was obtained from a type of shellfish found in the Medi-

terranean Sea. Thousands of these tiny animals are required to obtain as much as one gram of the coloring matter.

Mineral dyes. The colonial housewife made a type of mineral dye known as *iron buff* by placing scraps of iron in a barrel, covering them with vinegar and water, and allowing the mixture to stand. Homespun, soaked first in this solution, then in a solution of wood-ash, and exposed to the air, became the so-called iron buff.

Synthetic Dyes

The beginning of the present lack of popularity of the naturally occurring dyestuffs has been attributed to the work of H. W. Perkin, an English chemist. In 1856, while attempting to prepare quinine from aniline, he accidentally discovered a method for preparing synthetic dyes. His product, Perkin's mauve, completely revolutionized the dye industry.

Following his discovery, other brilliant-colored, aniline dyestuffs were produced in rapid succession. Chemists have succeeded in duplicating the natural dyes and have synthesized many others not found in nature. Coal-tar, which is deposited in the pipes and condensers in the manufacture of illuminating gas, was for many years considered useless but today is the principal source of most synthetic dyes.

Since the first dye to be synthesized was made from aniline ($C_6H_5NH_2$), the term aniline dyes is sometimes used to designate the whole group. Only a few of the large number are really aniline derivatives, the majority being made from such distillation compounds as benzene, naphthalene, anthracene, and the phenols.

In addition to these organic dyes, inorganic synthetic dyes or pigments are used. Chrome yellow, one of the most important of these dyes, is procured when goods are treated first with lead acetate and then with potassium dichromate.

PROBLEM 3. HOW ARE DYES FIXED ON TEXTILES?

In any consideration of the dyeing of textiles the following questions are raised: How do these dyestuffs become fixed on

the textile? Is the phenomenon of dyeing chemical or physical?

Relation of dyes and textiles. The exact nature of the dyeing process has been the subject of much speculation and research by many scientists. It was early found that the affinity between dyes and the various textile fibers differed. The cellulose fibers, linen and cotton, differ greatly from the protein fibers, wool and silk, in their reactivity toward dyes. The prevailing opinion for many years has been that the dyeing of cellulose fibers is an absorption phenomenon. The fact that cellulose exhibits neither acid nor basic properties and that the destruction of the activity of its hydroxyl groups does not change its dyeing properties supports this assumption.

The dyeing of protein fibers, on the other hand, has been held to be in the nature of a chemical combination. Wool and silk, being protein, exhibit both acid and basic properties and combine directly with either acid or basic dyes. If the acid group in these fibers is neutralized, their reactivity to the basic dyes will be markedly decreased, while their reactivity to acid dyes will be greatly increased. This seems to confirm the belief that the action of dyes on protein fibers is chemical.

In the most common method of dyeing a textile, the dye-stuff is dissolved or dispersed in the dye bath and the material is moved in the liquor or the liquor is circulated through the material. Often the temperature of the dyebath is raised to the boiling point, and usually additions of other compounds are made to assist in transition of the dye from the aqueous medium to the fiber. Although this sounds simple, it is a very complicated process. None of the theories so far evolved has succeeded in explaining all of the process. Each explains one or more of the factors involved. There are available today some 2,000 dyes for use on textiles. In this list there will be found a wide difference both in solubility and in reactivity with the textile fibers.

Dyes are classified as to their application under the following groups: acetate, acid, basic, diazotized and developed, direct, mordant and chrome, naphthol or azoic, sulfur, and vat.

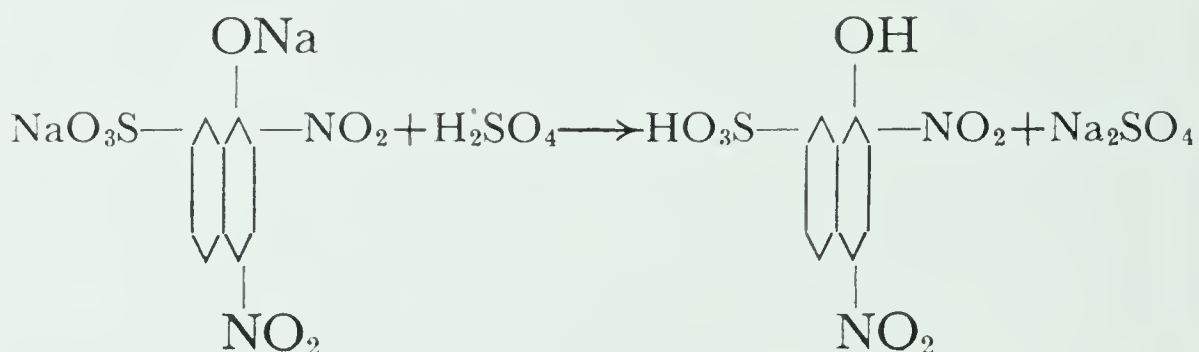
Acetate dyes. Acetate dyes are a group that was developed

in order to dye the cellulose acetate rayon, which differs chemically from the natural and most synthetic fibers. These colors are either direct or diazotized and developed on the fiber. There are two main groups of these complex dyes. Colors of one group are fast to pressing, dry cleaning, and perspiration, and colors belonging to the other group equal the vat colors in fastness to light but are less fast to washing and perspiration.

Acid dyes. Acid dyes are the sodium or calcium salts of colored organic acids and are divided into three groups, the nitro, sulfonated, and azo compounds.

The acid character of the molecule is due to the presence of a $-\text{COOH}$, a sulfonic $-\text{SO}_3\text{H}$, or a similar acid group.

Naphthol yellow S is a representative acid dye:



These dyes are acid in character and are used in an acid bath. The acid in the dye bath liberates the colored organic acid and also increases the reactivity of the protein fiber toward the dye. Protein fibers, like all protein substances, possess both acid and basic properties. The basic component of the protein molecule unites with the acid to form a colored compound.

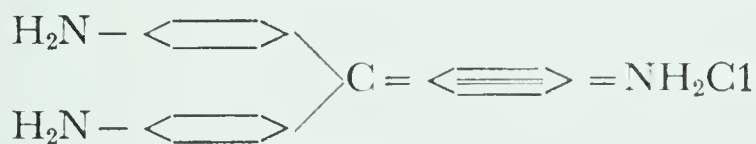
Acid dyes find extensive use in the coloring of wool and silk. Many of them are fugitive to light and washing; others are fast. They are often used to produce bright, delicate tints on silk, but are most satisfactory for the dyeing of wool. In the laundering of materials dyed with acid dyes, strong alkaline solutions should be avoided because the alkali has a tendency not only to injure the fiber but also to strip the dye from the goods.

Basic dyes. Basic dyes are salts of organic color bases. They are formed by the replacement of one or more of the hydrogen atoms of ammonia with other elements or groups. These dyes are basic in character and have the power to neutralize acids. They combine directly with protein, but cellulose requires a mordant before it will react with basic dyes. Tannic acid is commonly used for this purpose. The fatty acid of Turkey-red oil, which is formed by the action of sulfuric acid on castor oil, is also used as a mordant with basic dyes. Insoluble hydroxides, such as those of aluminum, chromium, iron, and tin, act as basic mordants when deposited on textile fibers. A variety of shades is produced by using different metallic mordants with dye.

Basic dyes produce brilliant colors that usually are not fast to light, laundering, or perspiration. Their chief use is in the dyeing of paper and leather and for topping off dull shades.

Perkin's mauve, the first synthetic dyestuff produced, is a basic dye. The uncombined base is colorless and usually insoluble in water; in combination with an acid it forms a salt which is colored and soluble in water. In such a solution the protein fiber plays the part of an acid, decomposes the dye salt, and unites with the basic portion of the molecule to fix the dye as an integral part of the fiber. Conditions leading to the maximum swelling of the fiber seem to provide for the greatest reactivity between the fiber and the dye.

Magenta is a basic dye.



Direct dyes. Direct dyes are cheap and easy to apply but of poor fastness. The process is one of absorption rather than chemical combination. These dyes, which vary greatly in chemical composition, are used especially for cottons and cotton-wool unions and for reused wool. Direct cotton dyes, being chiefly amines and phenols, are soluble in water, and hence, unless given further treatment, they are not fast to washing. Not all direct cotton dyes can be successfully after-

treated to make them more fast. However, a treatment with acetic acid together with sodium or potassiumdichromate renders certain colors less fugitive to washing, and treatment with copper sulfate increases their fastness to light. Some of the colors are still dull and uninteresting unless topped with bright basic dyes. The direct dyes, even with after-treatment to improve their fastness to washing and light, have not provided uniformly fast colors.

Developed direct dyes. Developed direct dyes are a class of direct dyes which contain an amino (NH) group, capable of being diazotized and developed to give a new dye with increased fastness to washing. In this development, a new dye is produced on the fiber which has increased fastness to washing. The direct dye is placed on the fiber in the usual manner and then diazotized and developed.

Mordant dyes. In the dyeing with mordant dyes, a mordant is required to combine with and fix the dyestuff. As chrome salts are the major salts used, these dyes are often spoken of as chrome dyes. The mordant dyes may be applied by three different processes; namely, top chrome, metachrome, and bottom chrome. Mordant dyes are used in the dyeing of wool and the printing of cotton. They are exceptionally fast to light, washing, and perspiration.

Azoic or naphthol dyes. This is a class of dyes that are considered as fast dyes. These dyes are actually made in the fiber. The chemical reaction involved is diazotization, the same reaction which is used with the developed direct dyes. Azoic dyes are employed in cotton piece dyeing and in cotton printing. The cotton may be impregnated with an alkaline solution of β -naphthol, a compound related to phenol, and dried in a well-ventilated, moderately warm room. The color is produced by introducing the thoroughly cooled treated fabric into a solution of a diazonium salt, which couples with β -naphthol and forms an insoluble colored compound in the fiber. By the use of various bases on the fiber, a wide range of shades may be produced that are fast to washing, light, and in some cases even to bleaching.

Sulfur dyes. Sulfur dyes have become important for pro-

ducing fast shades on cotton and other cellulose fibers including regenerated cellulose. The dye molecule contains sulfur and is insoluble in water but is soluble in sodium sulfide or other alkaline-reducing agents. The strongly alkaline bath prohibits their being used for protein fibers and cellulose acetate rayon unless a protective colloid is added to the dye bath or a special method of dyeing is used.

Vat dyes. Vat dyes are a group of insoluble compounds which are converted into an alkali soluble leuco derivative by means of sodium hydrosulfite and caustic soda; in this state they are applied to the fibers. In their reduced, soluble condition the vat dyes are colorless, but the color appears on reoxidation by exposure to the air. Indigo was the first vat dyestuff. Today it is synthesized from coal tar but is the same chemically as the natural product. Tyrian purple, another ancient dye, is a vat dye. Vat colors are unequaled in their fastness to washing, but some individual colors may not be fast to light. Therefore, the term vat dye, which is largely used as a standard of fastness, is not the equivalent of a guarantee of fastness to all conditions of use. Vat dyes are available in a wide range, exceeded only by that of the direct dyes, and are second in brightness only to basic dyes.

The Pad-Steam process is now being used in dyeing with vat dyes. In this process, the fabric is pigment-padded and thoroughly dried. After cooling, the fabric is passed through a "chemical pad" consisting of a solution of sodium hydrosulfite and caustic soda. From the chemical pad, the fabric passes to the steam chamber. The distance between the chemical pad and the steam chamber must be short, and the fabric is steamed for less than one minute. This reduces the vat dye and the leuco derivative evenly penetrates the fabric. The fabric is then oxidized with sodium perborate, scoured, and rinsed.

These new methods of processing recently developed will greatly extend the range of fabrics that can be vat dyed. These include more delicate fabrics, wools, and blends of natural and synthetic fibers.

The application of sulfur dyes and of vat dyes is similar

in that they are insoluble dyes that are rendered soluble by reduction and after being taken up by the fibers are made insoluble again. Sulfur and vat dyes differ from developed direct dyes and the azoic or naphthol dyes in that no new compound is created in the fiber when sulfur and vat dyes are used. (See page 123 for classification of dyes.)

Pigments differ from other substances used to dye textiles in that pigments are insoluble and have no affinity for the fiber and must be bound to it by an insoluble binding material. Pigmentation is a coating of a fabric and not a chemical action or even absorption as is the case with normal soluble dyestuffs. These pigments comprise a wide range of coloring matter including organic and inorganic compounds.

Selected pigments must be used with selected binders to give best results. The most modern and common type of application of pigments is by means of synthetic resins. In this form of application the pigment is carried in a resin dissolved in a volatile solvent.

Pigments possess superlative fastness to sunlight—a complete range of colors being available, all of which will withstand 300 hours in the Fadeometer. As the true shades of pigments are shown immediately after printing or dyeing, defects can be readily seen at the print machine and corrected. The penetrating properties and covering power of pigments allow the use of shallower engravings, thus the color material spreads farther and the print rollers can be used longer before it is necessary to re-engage them. The only after-treatment required when printing with pigments is that of drying.

Form in which textiles are dyed. Textiles are dyed in many forms. Wool is dyed in the form of fibers for dark colored goods that will be subjected to hard service. Each fiber is penetrated with the dye, and a uniform color results that does not alter with wear. Fiber dyeing is also commonly used for the purpose of obtaining intimate blends of colors. It is, however, the most expensive method.

A large portion of the textiles are dyed in the yarn. The dyestuff usually penetrates the yarn thoroughly, producing an

DYES	FIBERS TO WHICH APPLIED	PROPERTIES
Acetate	Acetate rayon	Fastness depends on quality and method.
Acid	Wool Silk Synthetic proteins	Fastness varies with dyestuff. May be fast to washing, light, perspiration and sea water. May be fast to washing or light or neither.
Basic	Wool Cotton Rayon	Brilliant in color. Fairly fast to washing on wool. Not fast to light and rubbing on cotton and rayon.
Developed direct	Cotton Linen Rayons	Fast to washing. Some possess good light fastness.
Direct	Wool Cotton Linen Viscose rayon Cuprammonium rayon	Fastness varies with the individual dyestuff. Not fast to washing, especially in dark shades; better on wool than on cotton. Fastness to light varies. Wide range of color—varied in brightness.
Mordant or Chrome . . .	Wool Silk	Fast to washing and light. Good penetration.
Naphthol or Azoic	Cotton Rayon	Fast to washing and light but tendency to crock
Sulfur	Cotton Linen Viscose rayon	Excellent fastness to washing; less fast to light, perspiration, acids and alkalies. Not fast to bleaching and oxidation. Dull and number of colors limited.
Vat	Cotton Linen Rayon	Excellent color fastness. Fastness varies with individual colors.
Pigments	Cotton Rayon	Fastness to washing varies. Fast to light.

even color. Yarn dyeing makes possible, through variation in construction, the production of checks, plaids, stripes, and various other designs as well as mixtures of color.

Piece dyeing is the dyeing of cloth in the piece by passing it over rolls into the dye vat. This method is the cheapest and is the most commonly used.

PROBLEM 4. WHAT FACTORS AFFECT THE FADING OF DYED FABRICS?

Light. One of the most important considerations of the consumer in the use of dyed textiles is the permanence of the dye throughout the life of the material. Of the factors responsible for the fading of dyed fabrics in everyday use, light is the most important. The brighter the illumination and the stronger the intensity of the light, the greater its fading action. The rays of the light as well as its intensity are important. There are in light not only the rays of the visible spectrum but also those invisible rays that have been shown to have such a drastic effect on dyes. It has been said that each and every part of the spectrum seems to have its function and influence in fading. To secure colors fast against sunlight is difficult, but colored fabrics may be obtained that are guaranteed fast to light for the life of the garment made from these goods. Research in this field is important to textile manufacturer and consumer alike.

Humidity. Humidity has been found to be an important factor affecting the fastness of the dyes, particularly in the case of cotton. In experiments with basic and azo dyes on cotton fabrics it was found that, when other conditions were the same, at a relative humidity of 100 per cent the rate of fading was three times as great as that at a relative humidity of 30 per cent.¹

Perspiration. The effect of perspiration on dyes has long been known to be destructive. Variation in the composition of the perspiration of individuals further complicates the

¹ S. G. Barker, "The Standardization of Tests for Fastness of Dyed Fabrics," *Textile Recorder*, Vol. 47 (Feb. 15, 1930), p. 65.

problem. Research has yielded results that make possible the production of dyes generally fast to this factor and some fabrics are guaranteed as fast to perspiration.

Laundering processes. Fastness of dyes to laundering processes has been urgently demanded by consumers. The complexity of this problem may well be considered. An article in use may be acted on by light, washed with alkali, subjected to dirt and perspiration, and again washed with alkali. The effect of the treatment on the fiber as well as on the dye as such must be considered. Further discussion of this subject will be found in Section Three.

Gas fumes. Dyes fast to light and laundering are often destroyed when subjected to gas fumes. This has been especially true with cellulose acetate rayon fabrics, but has been overcome by a special finish. In homes where the heat source is open gas stoves, many fabrics have been known to fade badly when hanging in a closet or even when folded in a dresser drawer. Improvement in the resistance of dyes to gas fumes has been noted.

Suggestion for the Laboratory

Test the fastness of dyed fabrics to light and laundering. Use Fadeometer or window box for light fastness tests.

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Unit Five

HOW DESIGN IS OBTAINED IN FABRICS

THE various textile industries are competing with each other in the production of cloth that will comply with the style trends or influence the trend in certain directions. The manufacturers of knitted fabrics endeavor to simulate the properties of woven goods by inserting extra yarns to give body to their cloth, and the weaver meets this competition by producing a lacy, elastic, woven fabric. The manufacturer of synthetic fibers is attempting to impart to his product all of the desirable properties of the natural fibers, and also to produce fibers and fabrics embodying service qualities and effects that cannot be obtained by the use of natural fibers. This effort on the part of the manufacturer to put out a fabric that will be a quantity seller results in the production of many novelty effects and variations. Variety may be accomplished by the combination of fibers in an unusual way, by the production of a novelty yarn, by a new or varied method of construction of the fabric, or by a special finish. New colors are developed to bid for favor, or unusual combinations of old colors meet the desire for something different. Though many variations, different colors, and novel effects are obtained without its use, design exerts a determining influence in the production of new fabrics.

What is meant by design? Design in some instances means simply a working pattern; in others it may be used to express the most pleasing division of spaces; but as applied to textiles, for this discussion we shall use the term to designate an orderly repetition of lines or spaces in such a manner that a figure is formed.

Twill weave may be regarded as having a design obtained by the orderly repetition of the diagonal line. Plain and satin weaves are without design as far as the weave is concerned. Novel effects are produced in tweeds by a combination of colors in the spinning of the yarn, but, since there is no order in the repetition of the color, the result is not a design. Rayon, in combination with wool or cotton in the formation of the yarn, when used in regular order, produces a novel effect without design.

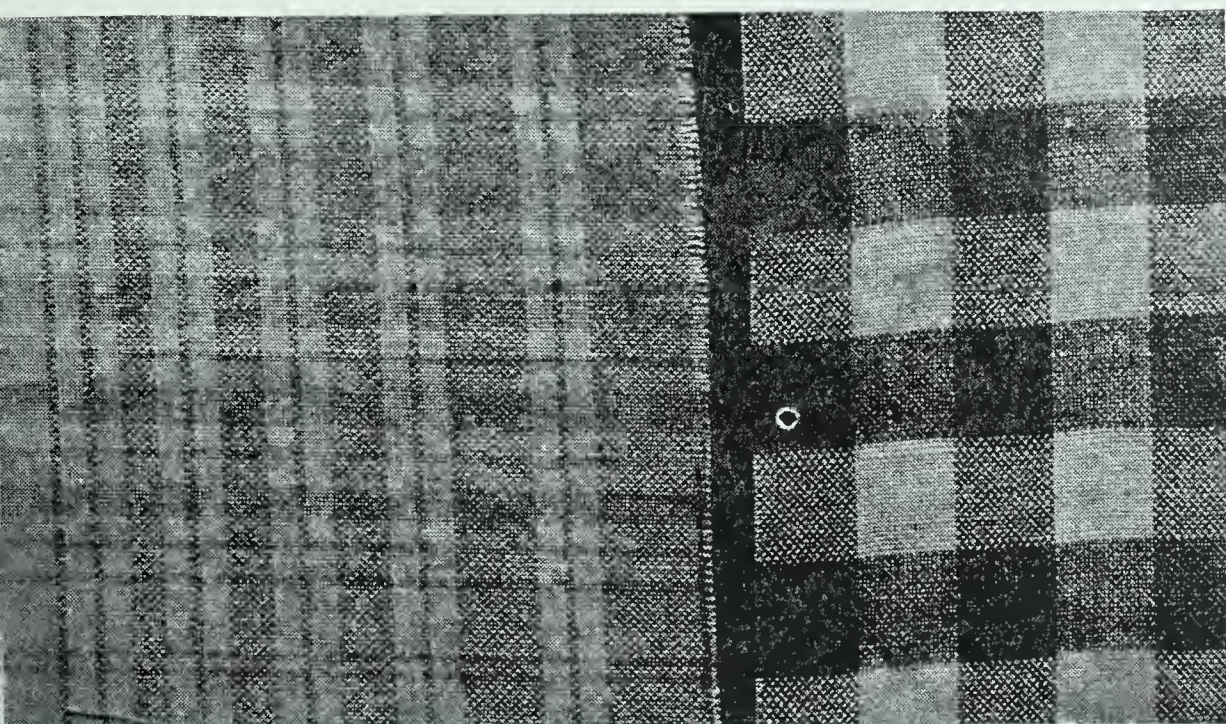
The examination of several fabrics which have a figure will show that in some of them the design was formed in the construction of the fabric and in others it was added as a part of the finishing processes. On this basis the classification of textile design may be designated as *structural* and *surface*. The design in blue-and-white checked gingham is structural, formed during the weaving; in a black-and-white percale it is surface, added in the finishing.

PROBLEM 1. HOW IS STRUCTURAL DESIGN OBTAINED?

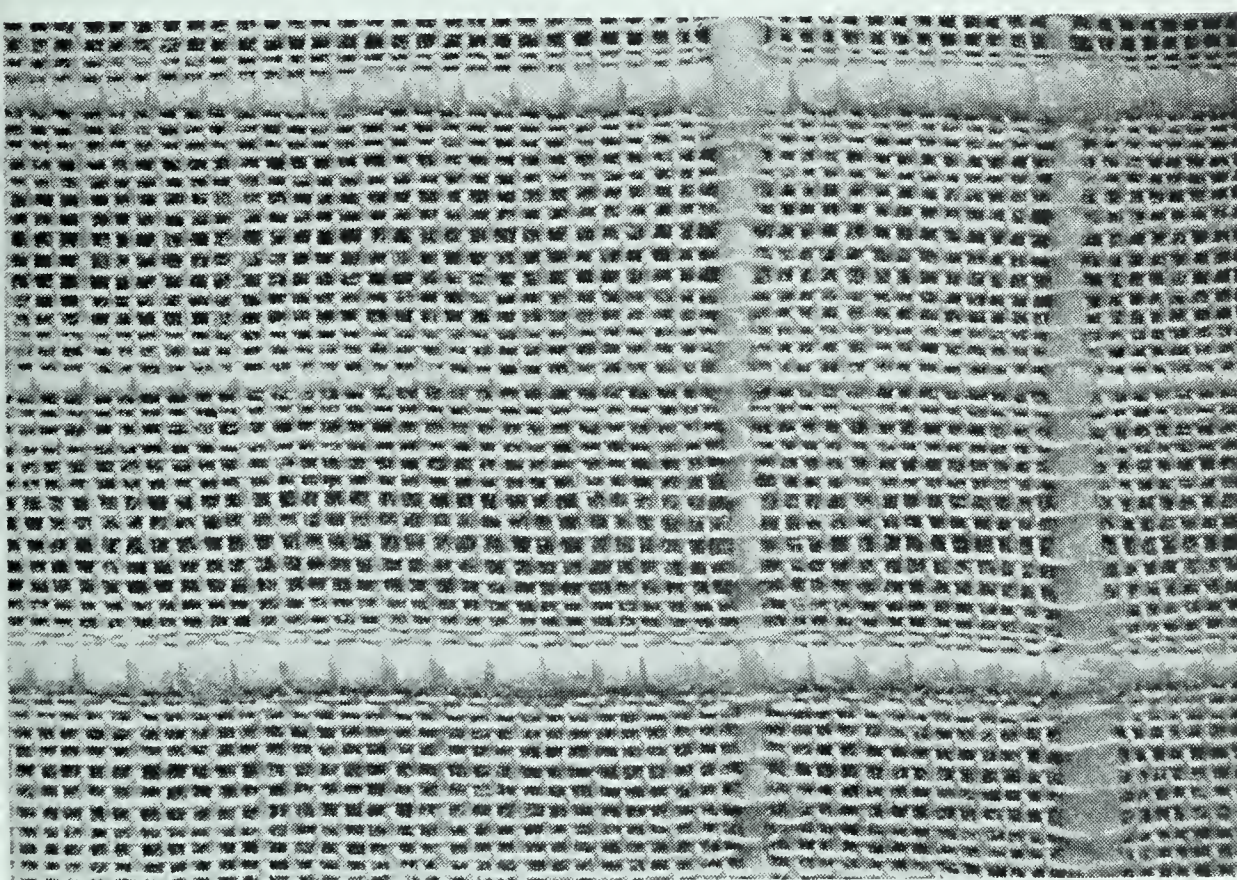
Since structural design is formed when the fabric is produced, it necessarily results from variety in the material used, from the method of its use, or from a combination of these two factors.

Variety in the material used. The material used in the construction of fabrics is usually yarn of some kind. Recalling our discussion of yarns (Unit Two) we know that yarns are classified as simple and complex, depending upon their structure. We also know that simple yarns vary as to ply, color, size, direction, and amount of twist and that complex yarns vary according to the manner in which they are made. By the use of similar yarns of only two colors a manufacturer can produce fabrics presenting a wide range in structural design. (See page 129.) Given white and blue yarns of the same size, what effects could be produced in plain woven fabrics by varying the massing of the color?

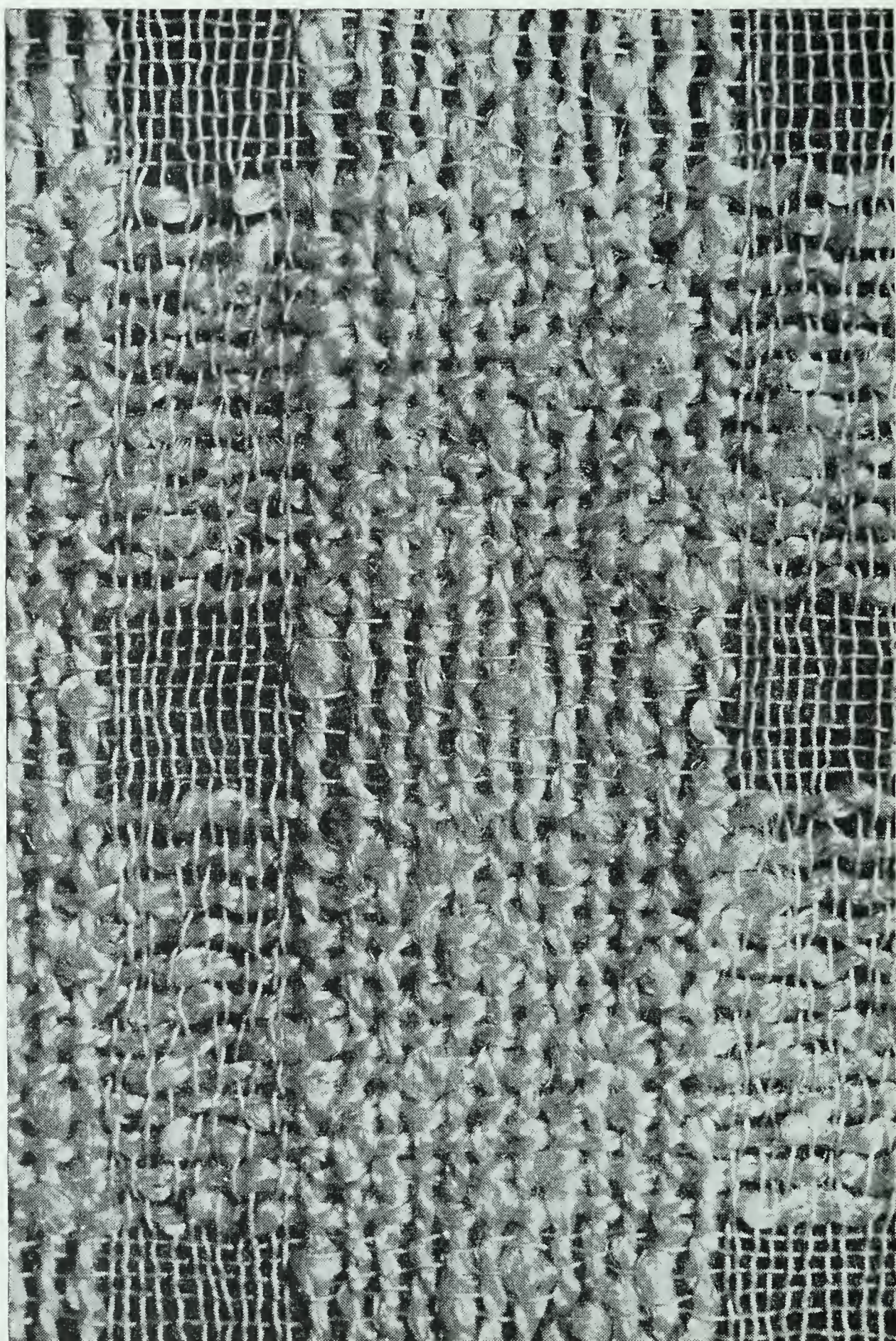
In a striped or checked white fabric a heavier yarn, that is, one of larger size, may have been added to form a pattern. (See



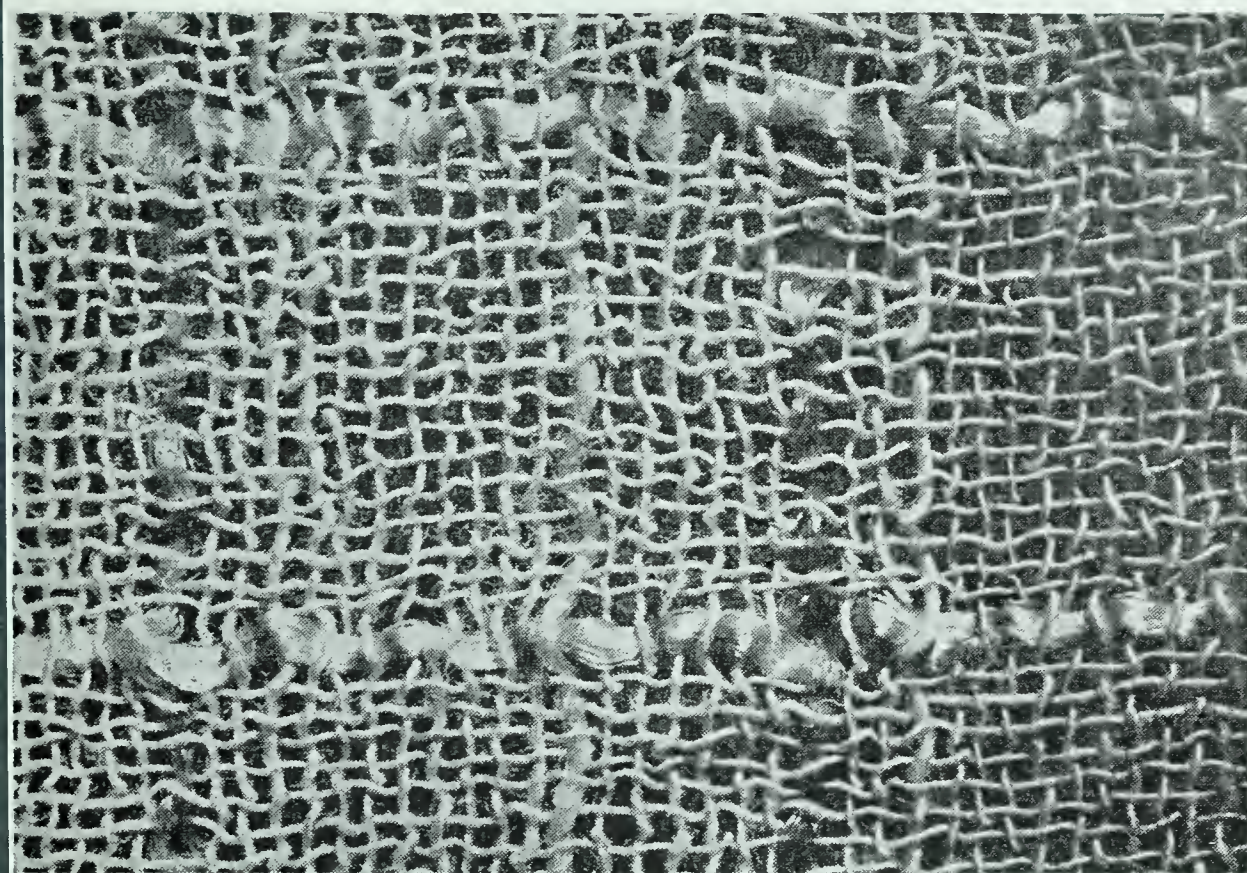
These designs were produced by similar yarns of two colors.



This design was produced by means of variation in the size of the yarn used.



Fine simple yarns combined with heavy complex yarns in creation of design.

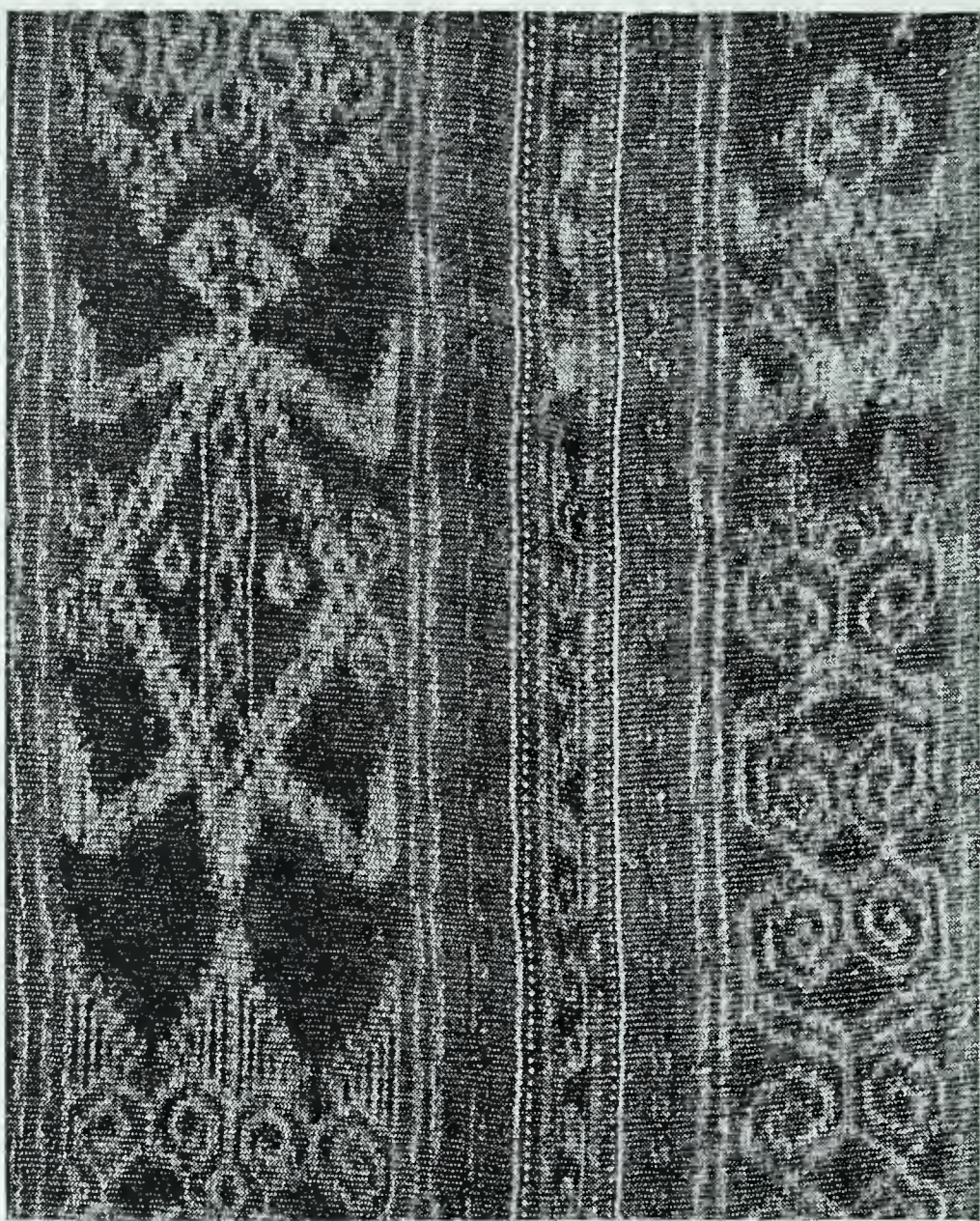


Design resulting from use of different fibers.

page 129, top.) This larger yarn may be either single strand or ply but all of one color. In other instances the yarns differ in color, size, or twist, or a complex yarn has been added to form a stripe or check. (See page 130.) If a heavy yarn forms the design in a fabric made from fine yarns, the cloth may split as a result of the cutting of these yarns where they cross the heavier ones.

Yarns treated to prevent shrinkage may be woven with yarns not so treated, and in the finishing and subsequent shrinkage of the fabric a design is formed. A two-tone effect may be obtained in design by weaving in a pattern, yarns that have been so treated that they will absorb the dye more rapidly than the untreated yarns used with them.

The use of yarns spun from different fibers affords another means by which structural design may be produced by a variation in the material used. Patterns may be formed by the use of yarns of the same color and size, varying only in the fibers from which they are spun (See page 131); however, this rarely serves by itself as a basis for structural design but



Primitive warp dyeing as done by savage tribes in the Philippine Islands many years ago. The design was described by a tribesman as "a spider within a spider" and was said to refer to the cannibalistic practices of the people in early days.

usually supplements in interest a figure produced by color or by weave.

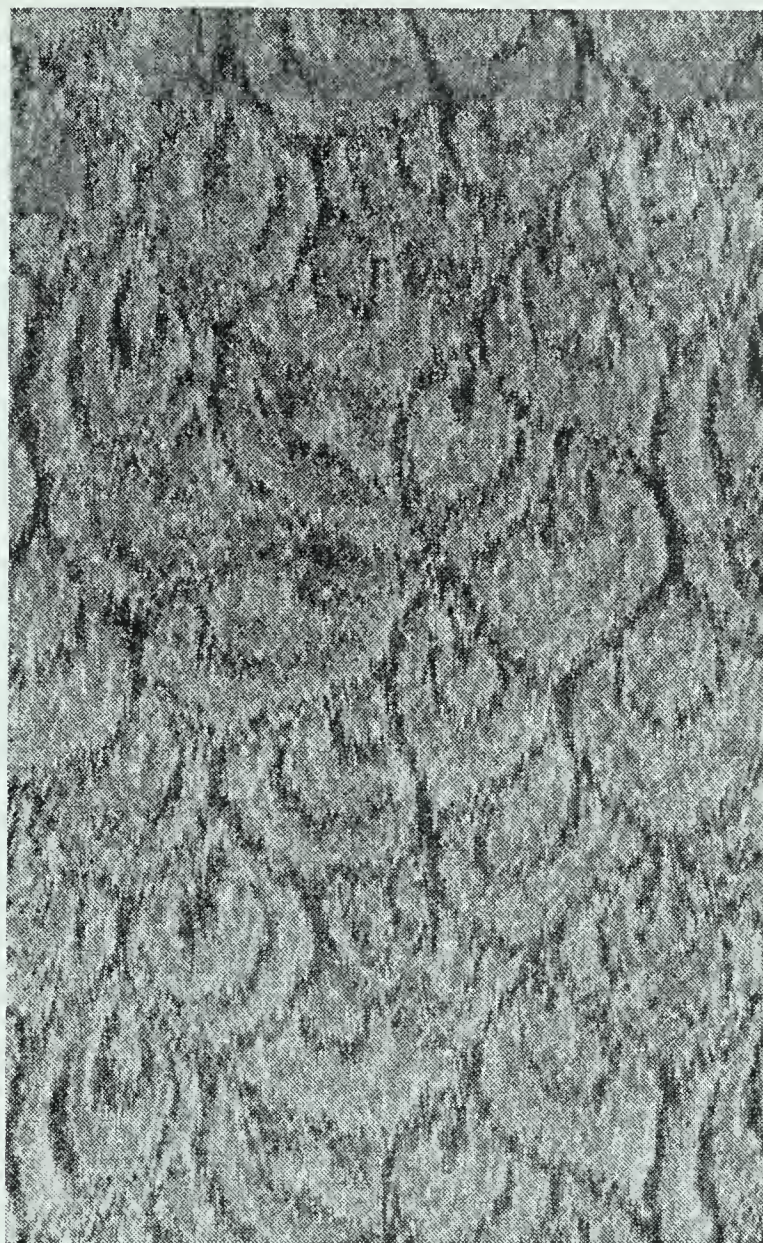
Metallic yarns, when the vogue, serve as an effective means of introducing a design through variation in the material used. These yarns may add color as well as sheen. By various methods of finishing, metallic yarns and fabrics can be so protected as to prevent their tarnishing. When this is done such fabrics usually give satisfactory service.

There seems to be no limit to the number of designs it is possible to produce by means of combining different types of yarns. New and novel effects are continually appearing in which either a new fiber has been used to make the yarn or the yarn has been constructed in a novel way or has been given an unusual finish.

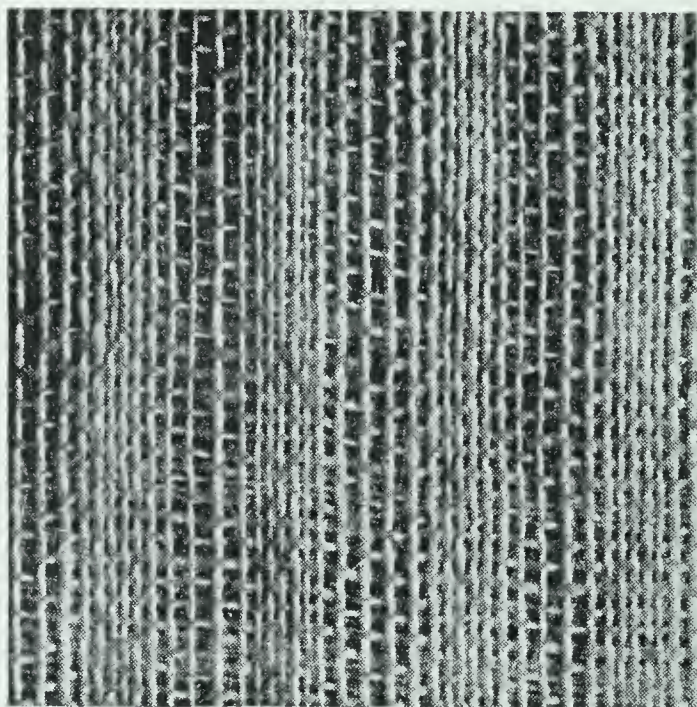
Warp printing is a method of obtaining design in fabric by placing the design, in colors, on the warp yarns before weaving.

In earlier days this was accomplished by protecting the part of the warp that was to remain undyed by tight and careful wrapping. When the yarns were immersed in the dye, the unwrapped part took up the color. This process is illustrated on page 132. At the present time the design is stamped or printed on the warp yarns before they are woven. The resulting effect is quite different from that produced by fabric printing, as crossing of the filling yarns gives a soft, indistinct effect to the design. (See the illustration above.)

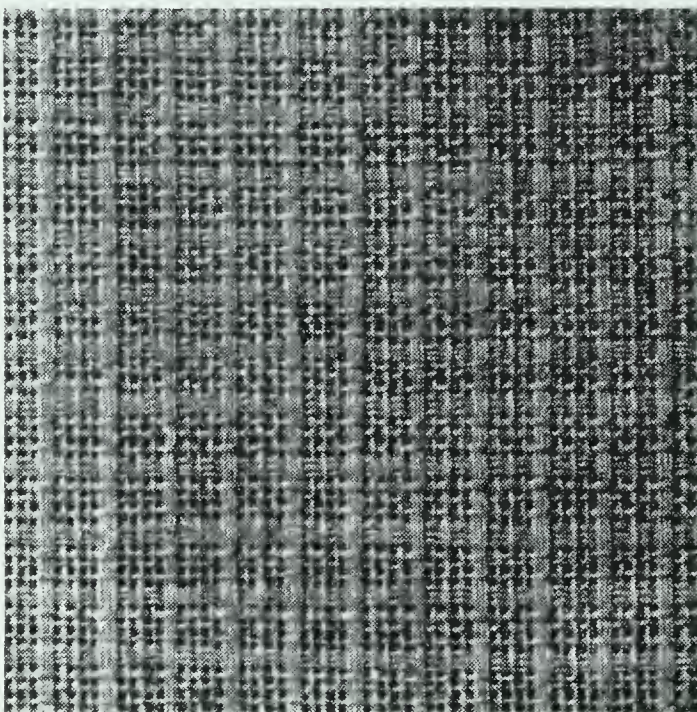
Method of use. The way in which yarns are used in weaving is an important means of producing structural design.



Modern warp dyeing in which the design is printed on the warp. Note the indistinctness of the pattern.



Design produced by grouping of yarns.



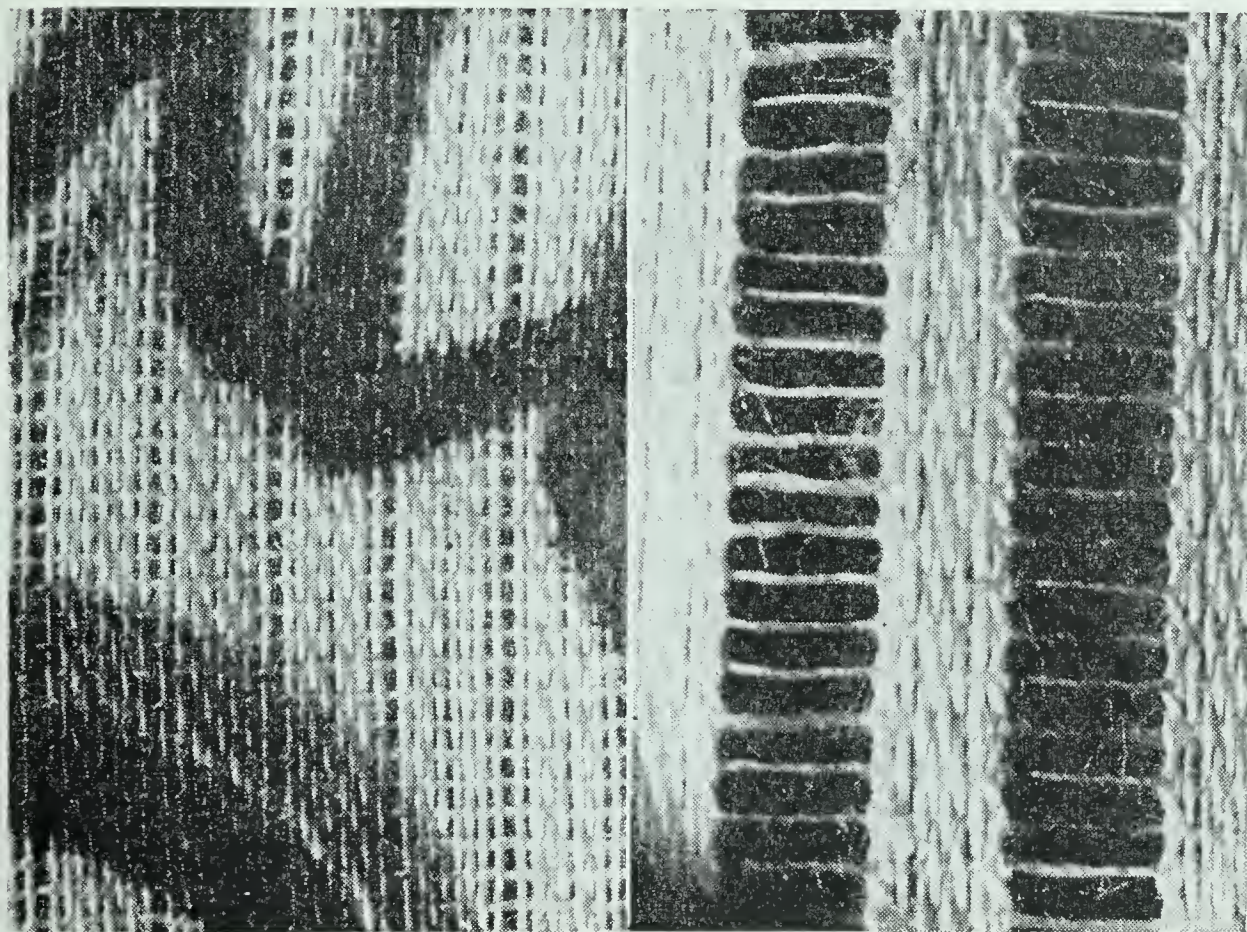
Ply yarns and grouping combined to create design.

There are only two ways in which the use of yarns can be varied. These are by the grouping of the yarns and by the method of interlacing.

Grouping of yarns. It is possible to secure a variety of effects with yarns of the same color, size, and fiber by grouping them in certain ways. A grouping of both warp and filling results in the formation of a check. Lingerie cloth and pajama check are familiar examples of this. The grouping of the warp is accomplished by a difference in the reed spacing. (See top left.) The grouping of the filling is the result of a variation in the speed with which the cloth is wound onto the cloth roll. By using several yarns as one, the effect of a heavy yarn may be obtained. Fine yarns grouped in this

manner will tend to flatten when pressed and thus reduce the tendency to cut the yarns that cross them.

Some seersucker is a form of structural design in which the crepe stripe effect is produced by weaving stripes of warp ends under the usual tension alternately with other groups

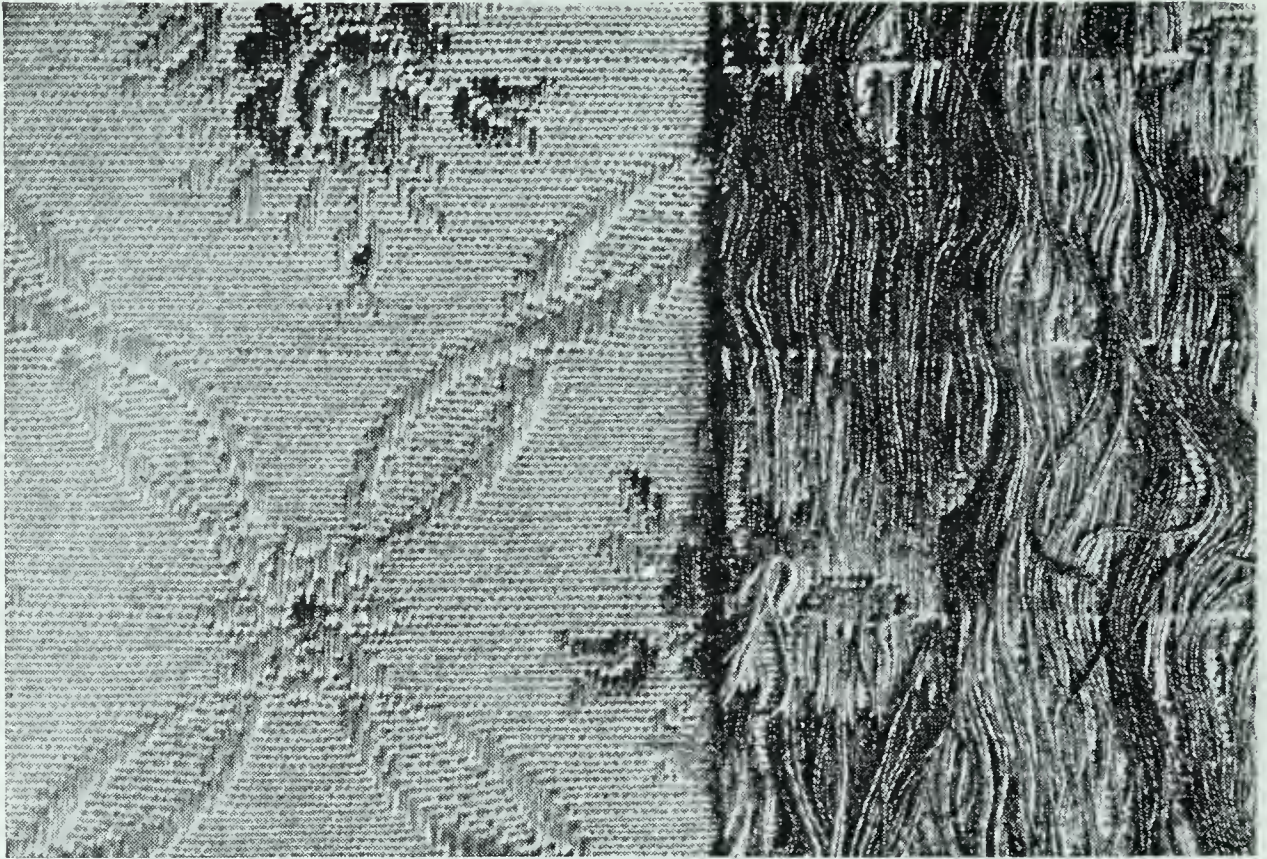


Structural design produced by grouping of yarns.

Structural design produced by grouping of yarns. One row of gauze weaving prevents the yarns from slipping but does not influence the design.

which are slack or under no tension. Washing and ironing will not remove the crepe effect in these woven seersuckers but will affect seersuckers produced by finishes.

The method of interlacing. The method of interlacing or the type of weaving is another means of producing design by variation in the method in which the yarns are used. All of the weaves in which a design is formed in their construction would fall under this classification. The three weaves, spot, swivel, and lappet, in which an extra yarn is used only for decoration, as described in Unit One, are important illustrations of this method. Twill, figure, and double weaving, when used to form a design, are other illustrations. Materials such as brocades in which the decorative yarns are not cut but are allowed to float on the back of the cloth are suitable



Brocaded fabric. Left, front; right, back.

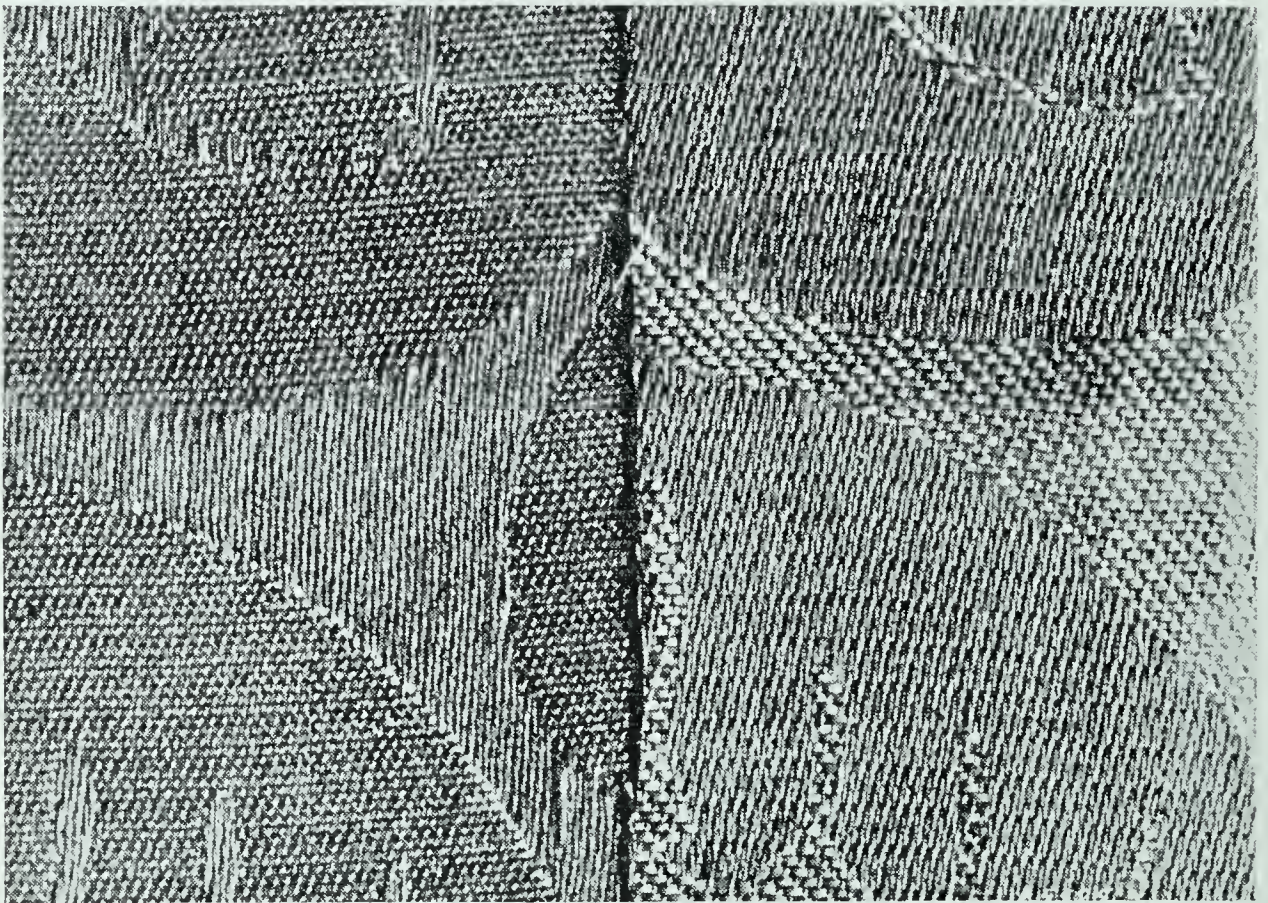
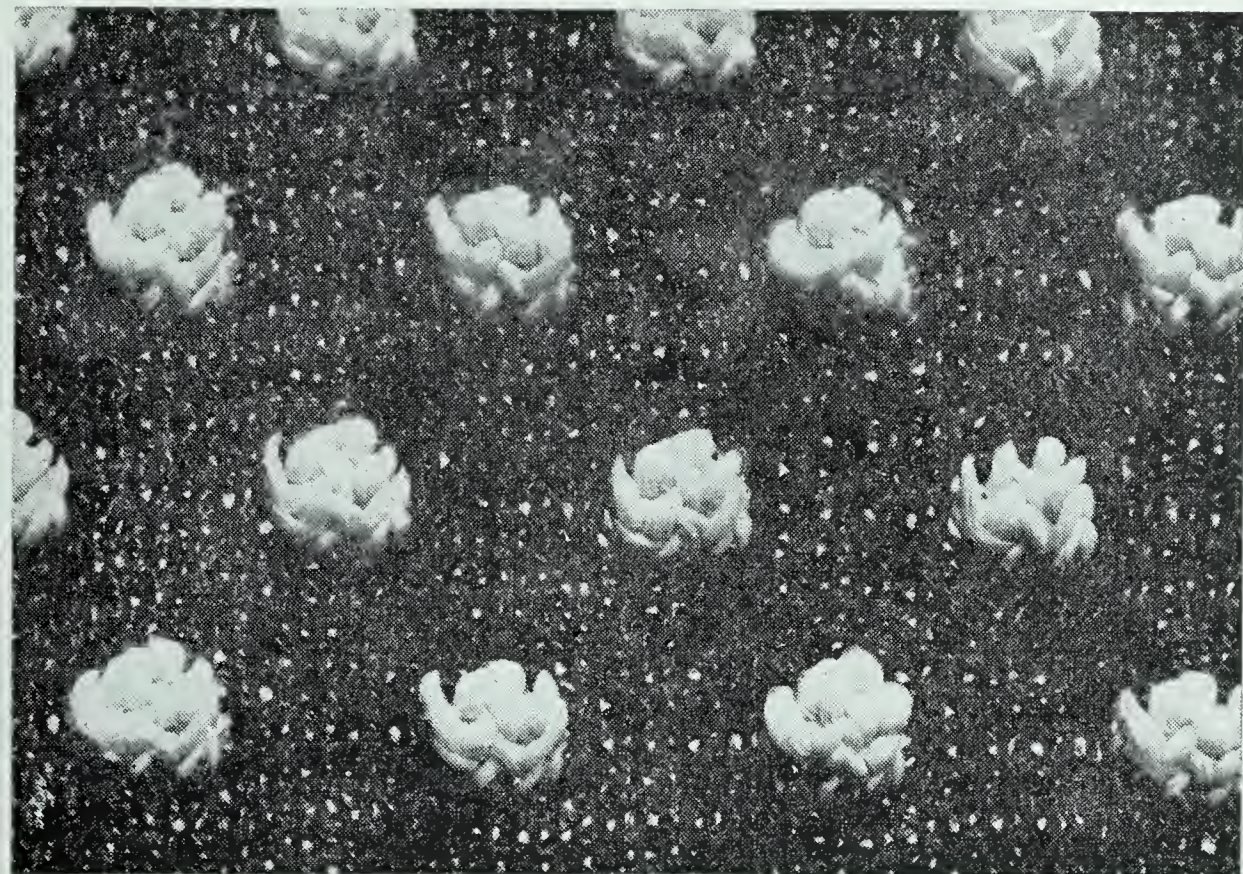


Figure weave. Left, front; right, back.



Structural design in knitted fabric. Top, right side; bottom, wrong side.



Courtesy The Bettmann Archive

Printing of cotton in America, early nineteenth century. Woodcut from "Young Tradesmen."

for use only as hangings or when lined to prevent wearing of these long floats. (See the illustration at top of page 136.)

Figure weaving. All the methods of obtaining structural design that have been discussed may be used in any one weave. However, the design may result from a combination of two or more weaves or their variations. (See the illustration at bottom of page 136.)

This method of combining two or more weaves or in some way changing the method of interlacing is known as *figure weaving*. It is one of the most important methods of obtaining structural design. Elaborate figure weaves are produced by the Jacquard and are sometimes designated as Jacquard weaves. Because of its use in the construction of table damask this weave is often known as *damask weave*.

Figure weaving alone or in connection with other methods, that of a combination of different colors, or a combination of differently spun yarns, or a combination of fibers, furnishes a wide scope for design in fabrics. Shirting madras illustrates a combination of colors, fibers, and weaves. In such material, large patterns in which long floats are thrown to the surface are to be guarded against, as they will tend to catch and break when the fabric is subjected to wear.

Along with the production of elaborate design in woven fabrics, various methods have been evolved by which similar designs may be obtained in knitted materials. (See page 137.) The development of warp knitting offers unlimited opportunities for producing a design as the fabric is constructed. The discovery that the Jacquard attachment could be used in connection with knitting machines furnished the necessary method. All of the various types of structural design as described may be produced in the construction of knitted fabrics. The combination of fibers, especially that of rayon with wool or cotton, is widely used to produce structural design in knitted fabrics.

Suggestion for the Laboratory

Study fabrics illustrating various methods of obtaining structural design in woven material. If possible, obtain the same illustrations in knitted fabrics.

PROBLEM 2. HOW MAY SURFACE DESIGN BE APPLIED?

Surface design is as important in the production of pleasing fabrics as is structural design. Printing, moiré, applique, and embroidery are methods by which design is applied to the surface of cloth. In the use of surface design the artist has greater freedom, being less limited by the mechanics of the process.

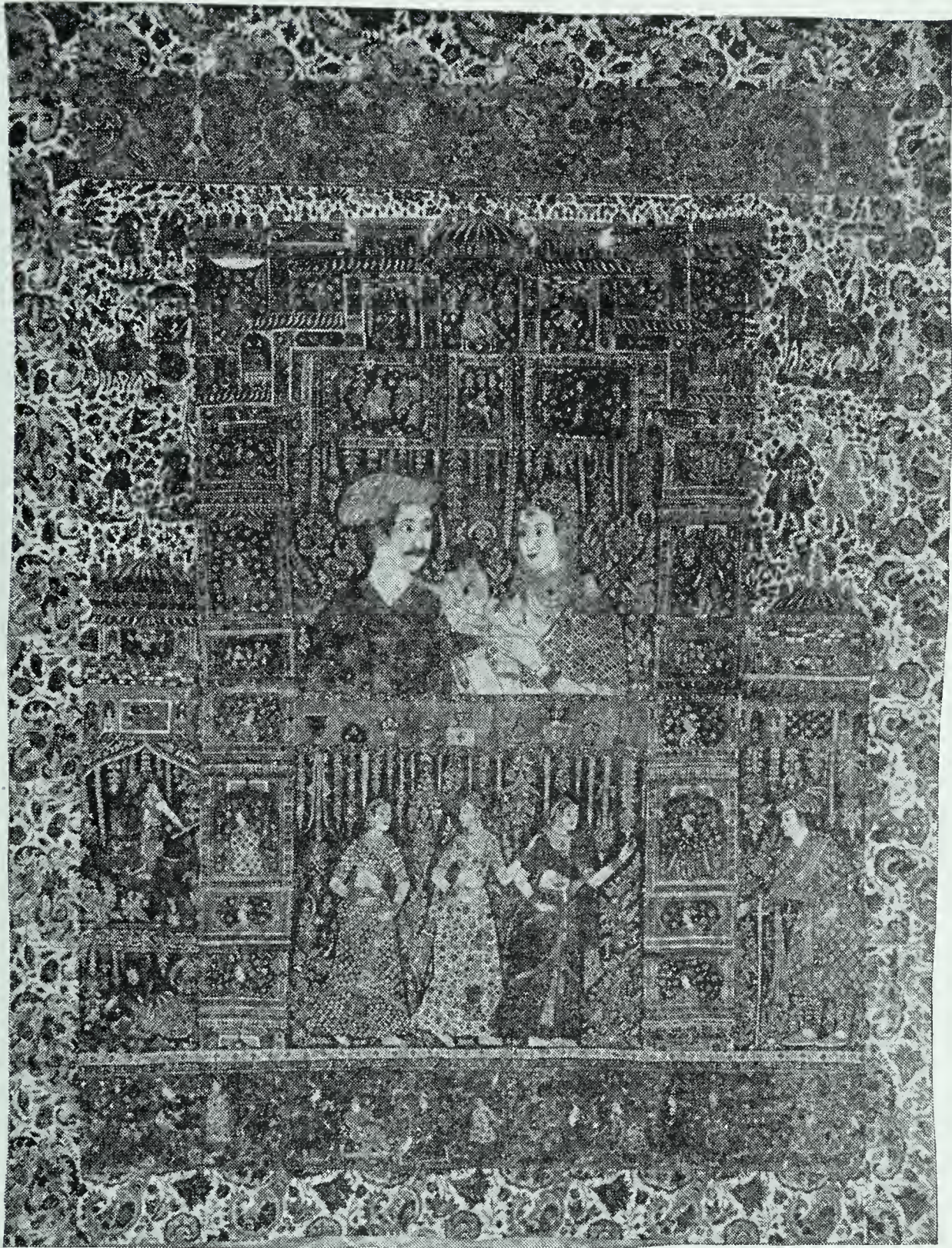
Printing. Printing, which is the application of dyes to the surface of cloth, usually in selected areas only, is by far the most important means of obtaining surface design. This method makes available at a relatively low cost elaborate patterns in variegated colors artistically blended. Colors added to the surface of a cloth are no longer considered less durable than those added to the fibers or the yarns before the fabric is constructed.

In printing, there must be some special means by which dye is applied and fixed to the surface of the cloth. The same dyes are used in printing as in regular dyeing where the fabric or yarns are dipped into a dye bath, but instead of the thin dye-bath solution, thicker combinations are used for printing. These usually contain sizing material such as starch and are in the form of a thick cream or paste.

The origin of printing textiles is not known but hand painting, resist dyeing, and block printing were used by primitive man in many countries. (See page 138.) Hand decoration is found in India and Java in the well known batik work and in many parts of the Orient in tie-and-dye fabrics. (See the illustrations on pages 142 and 154.)

The three important methods of printing textiles are block, stencil or screen, and roller.

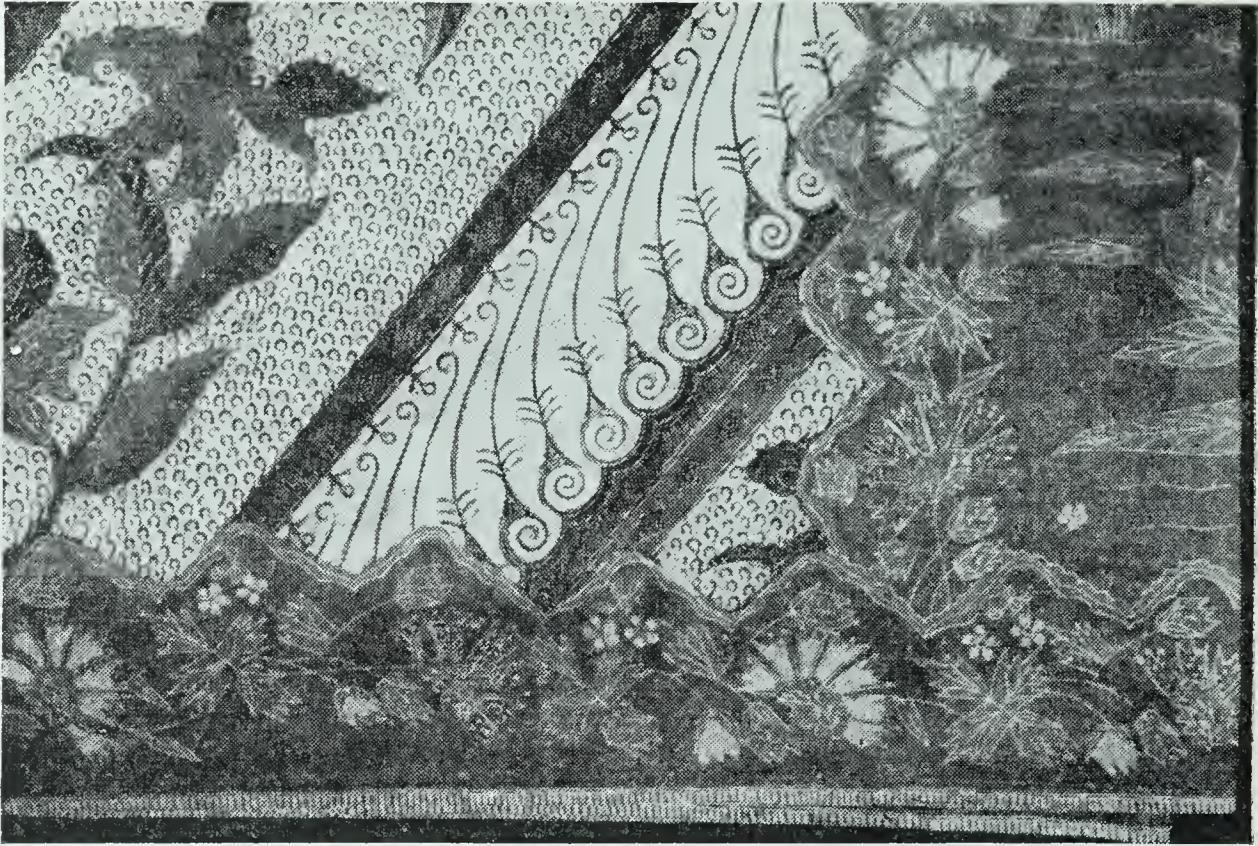
Block printing. Block printing, one of the oldest forms, was originally done only by hand. Today it is done either by hand or by machine. Hand block printing is one of the slowest and simplest of methods. The design is cut out in relief in a suitable type of wood or other material. (See page 138.) If the design includes fine lines, this effect is obtained by using metal pins or strips. If a small design is desired, the entire



Courtesy The Metropolitan Museum of Art

Painted cotton wall hanging. (Indo-Persia.)

figure is cut in the block; in case of a large design, only a portion of the figure is cut in one block. A separate block is usually prepared for each color to be applied, the dye is added to the block, and the design is stamped by hand on the surface



Batik, a form of resist printing. Elaborate design in many colors, produced by hand. (Java.)

of the fabric. This permits the production of original artistic effects with little cost, except for labor.

In 1770 the first machine to aid in the printing of fabrics was constructed. This, a type of block printing machine, was in the form of a press which made possible the printing from copper plates. The machine is used today only in Switzerland for the production of very fine work. The design is cut into copper plates which are not so limited in size as the hand blocks because they are placed on a carriage which slides back and forth under a roller. The employment of larger blocks permitted the use of larger, more flowing designs and greater perfection of detail. (See page 144.) At first the copper plates were engraved by hand, but in 1803 Widmer¹ applied a method used to engrave copper rollers to the engraving of copper plates.

Machine block printing known as Perrotine Printing was

¹ Henri Clouzot, *Painted and Printed Fabrics*, p. 22. Copyright, 1927, by the Metropolitan Museum of Art.



Courtesy The Metropolitan Museum of Art

"Le Petit Buveur," monochrome block print. (Jouy, about 1770.)



Courtesy The Metropolitan Museum of Art

"Les Travaux de la Manufacture," copperplate print depicting the steps in the manufacture of cloth. First pattern designed by J. B. Huet for the Manufacture Royale de S.D. and Oberkampf, about 1784.

not developed until 1834. The eleventh edition of the *Encyclopedia Britannica* states:

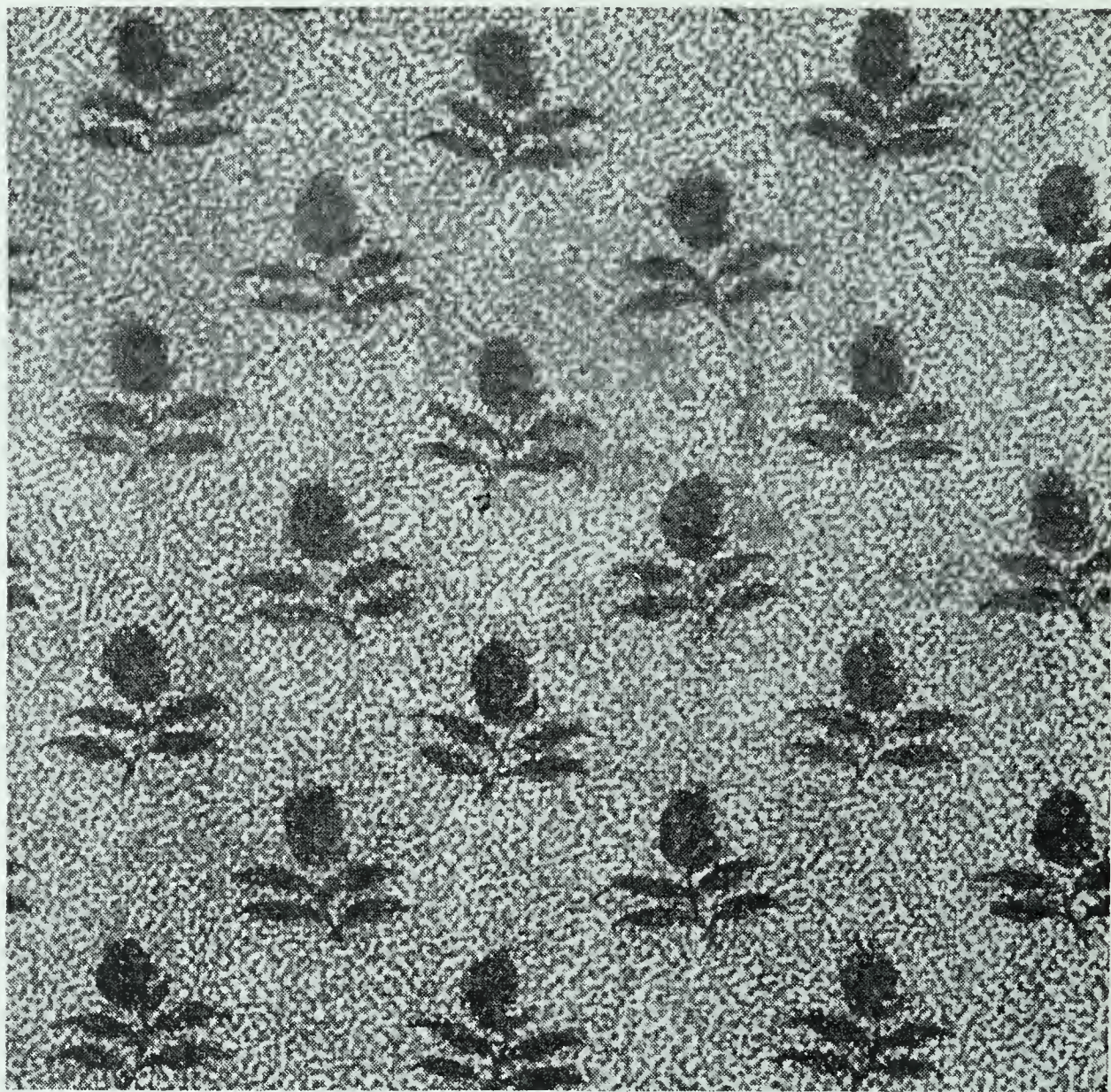
The Perrotine is a block printing machine invented by Perrot of Rouen in 1834 and, practically speaking, is the only successful mechanical device ever introduced for this purpose. For some reason or other, it has rarely been used in England, but its value was almost immediately recognized on the Continent and, although block printing of all sorts has been replaced to such an enormous extent by roller printing, the Perrotine is still largely employed in France, Germany, and Italy.



Courtesy The Metropolitan Museum of Art

Pastoral, copperplate print. (England, about 1765.)

Screen printing or stenciling. Stenciling is an art that has long been used by the Japanese. For this work a pattern is cut from firm paper or other suitable material, the portion of the design to remain in natural color being left uncut. This pattern is laid over the cloth and dye is brushed through the openings. Stenciling is a hand process by means of which original patterns may be applied successfully to such articles as curtains and scarfs. A stencil machine was perfected in 1894 and is used to some extent today.



Courtesy Museum of Fine Arts, Boston

American printed cotton, early eighteenth century.

Modern spray printing may be considered a variation of stenciling in which the dye is applied by air pistols. The stencils are inexpensive and there are no limits of size for the articles. Spray printing is especially suitable for the printing of tablecloths and bedspreads. The color paste is applied by means of air pistols using compressed air. All types of dyes are suited to this process, and the finishing of spray prints is the same as for any other process of printing.

Screen printing, which may be considered as a modern form of stenciling, is especially adapted to the use of large designs or elaborate prints where only a limited yardage is desired. Formerly, silk or copper gauze was stretched and fastened to



Courtesy The Metropolitan Museum of Art

Polychrome cylinder print. (England, about 1830.)

a framework of the desired dimensions in the full width of the cloth. Today, nylon, vinyon, or glass fabric may be used for the screen. A separate frame is prepared for each color in the design and the portion to be printed in one color is placed on a screen. One method of applying the design to the screen is to coat the screen on both sides with a thin film of a soluble glue or gelatine. Light sensitive lacquers may be used instead of the gelatine. The design is then produced on some trans-

parent sheet by means of a light-resistant pigment and the screen is covered with this sheet. Exposure to light causes the soluble film to become insoluble where it is not protected. The soluble material which is then in the design only is removed by washing with water. Thus a screen is prepared with the untreated gauze in the form of the desired pattern and the remainder of the screen blocked out. A set of screens for a six-color design can be prepared in four or five days, while a similar set of rollers would require a similar number of weeks to prepare.

A firm, smooth-topped table is required for the preparation of the cloth. The table is first covered with a thick pad of felt, over which is placed a rubber blanket or a particular type of cloth. The fabric to be printed may be pinned or pasted to the table.

The screens are placed in order over the cloth and securely fastened. Color paste is forced through the mesh of the screen by means of a squeegee. This method of printing is economical in the production of small lengths of cloth or for special orders. It is several times as fast as block printing. With proper care, a set of screens can be expected to print four thousand yards of fabric.

Screen printing is more flexible than roller printing. A new design can be set up in less time and with less expense than can be done with roller printing. Within the last fifteen years, screen printing has developed from a process limited to the production of articles such as tablecloths, scarfs, and draperies to one suited to the production of all types of fabrics. However, the classes of dyestuffs that can be used are limited, and this method of printing is most successful when used for novelty and quality products.

The greatest development has been along the line of equipment for pasting the fabric to the table. This method replacing the slow method of pinning has cut the time of preparation of the fabric and has increased the accuracy with which the design can be applied. Other improvements have been in mechanical squeegees, improved metal frames, and metal-

constructed tables; more durable screens with finer designs by means of photo engraving; quick drying of the cloth; and semi-automatic and fully automatic printing machines.

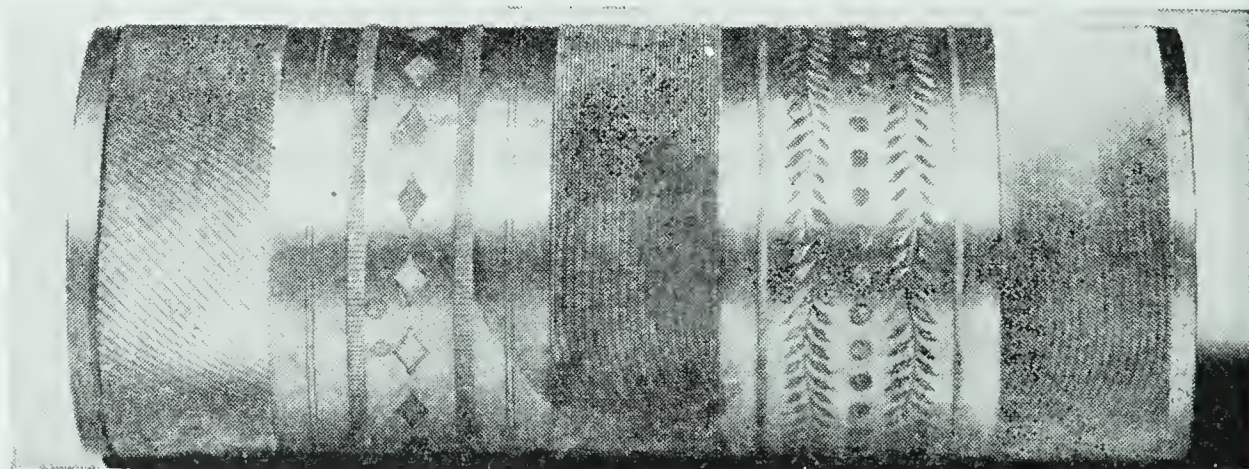
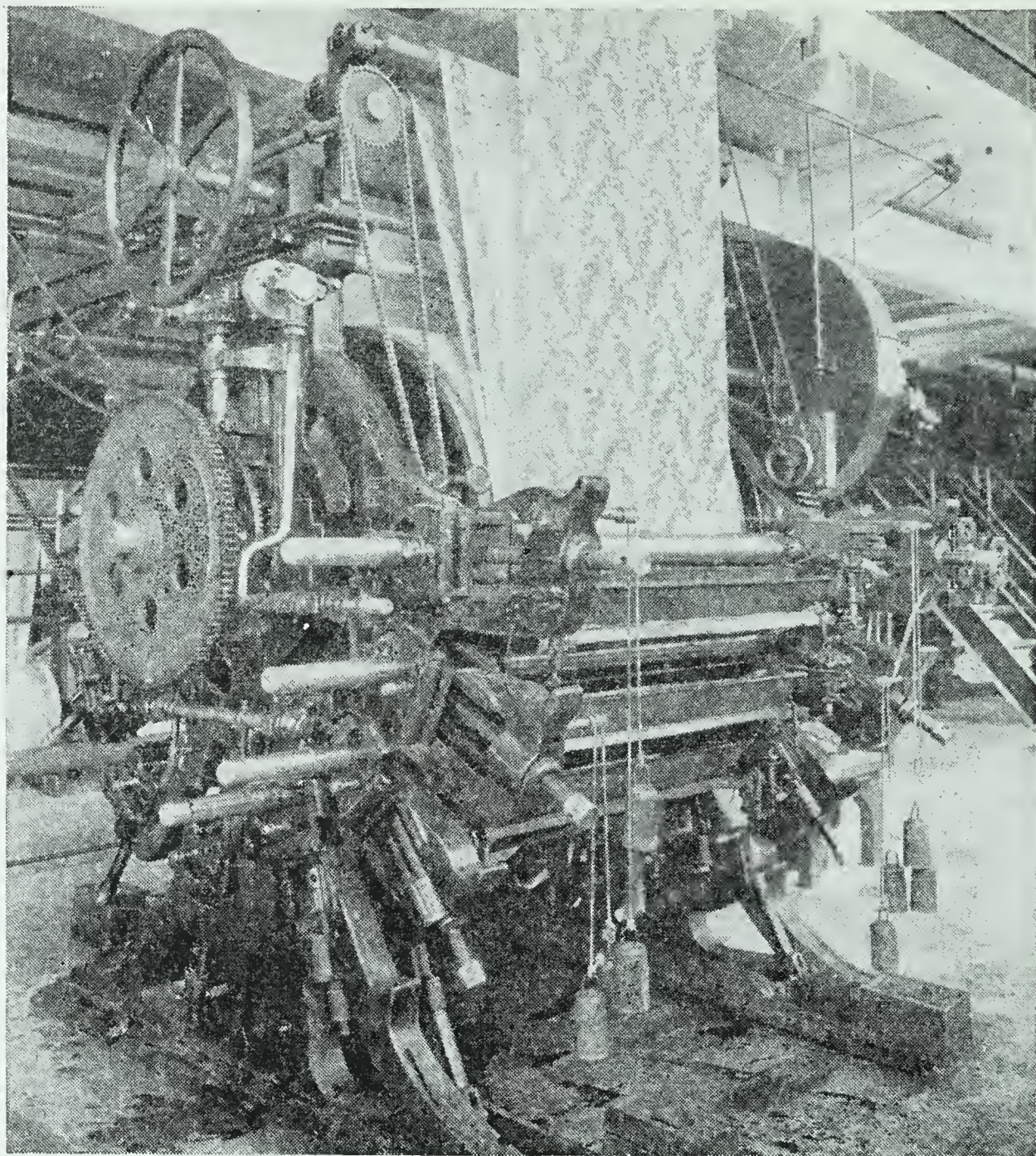
To dry the fabric between the printing of different colors has been one of the most difficult problems. First, steam coils were placed under the table tops but this was not very successful. Then a method of blowing warm air over the fabric was tried. The latest and most successful method is drying by means of infrared lamps.

Roller printing. Authorities do not agree as to either the date or inventor of copper-roller printing. Fabrics decorated by this method were produced in France in 1797 when a machine was constructed in the workshop of Oberkampf. However, credit is given to Thomas Bell, who conceived the idea as early as 1770, it is claimed. Although machine block printing and hand block printing are used to a limited extent even today, roller printing has replaced other methods for quantity production of surface design. (See page 150.)

A roller printing machine includes a large pressure bowl, around the bottom half of which are located the engraved rollers approximately five inches in diameter. (See page 150.) Each roller is supplied with its own color trough and feed roller. The furnishing or feed roller revolves in the dye bath and feeds the dye paste onto the engraved roller. A sharp-edged metal blade, known as a doctor, scrapes the dye off the unengraved portion of the roller. The dye is transferred to the cloth by the revolving engraved roller as the cloth passes around the pressure drum. Each roller transfers its portion of the design to the cloth as it comes in contact with it.

The expense of this method lies in the production of one or many engraved copper rollers for each design. However, by this method 10,000 to 12,000 yards of fabric may be printed by one machine in 10 hours.

The accurate engraving of the copper roller is one of the most important parts of the roller printing method. The design may be engraved by hand, by etching with nitric acid, or by indenting the pattern by machine.



Courtesy Rice, Barton and Fales, Inc.

Top, an eight-color printing machine, showing fabric as it leaves the machine. The color pans and copper print rolls are also visible. Bottom, experimental copper roll.

The engraving of the cylinders by hand was a process long, costly, and delicate, and in the case of the majority of patterns, even impossible. After many attempts, however, Samuel Widmer found in 1801 a method of engraving the cylinders by means of steel points driven into the copper by machine, an apparatus that, automatically operated, moved the length and breadth of the cylinder, allowing the design to be retraced thousands of times on the copper. This machine accomplished in five or six days work that formerly required six months to engrave by hand.¹

In the etching process of engraving the rollers, an enlarged image for the design is cast upon a zinc plate. This design is then printed in color and the outlines are engraved by hand. A pantograph machine is used to transfer the design in reduced size onto a varnished or lacquered roller. In the transferring of the design, diamond points cut the outlines of the design through the varnish with which the roller is protected. Each diamond point cuts one repeat of the pattern, and a separate roller is prepared for each color in the design. The roller is then revolved in a shallow trough containing nitric acid. The acid acts only on those portions of the roller where the varnish was cut away. When the design has been etched sufficiently deep, the roller is removed, washed, and the varnish dissolved off. If necessary the design is touched up by hand.

In engraving the rollers by machine, the pattern is impressed in the roller by a small cylindrical "mill" on which the pattern is in relief. To prepare this a soft, highly polished steel roller is engraved by hand with one repeat of the pattern. This roller is treated to harden it sufficiently so that it can be used as a "die" from which to prepare the mill. The mill is prepared with the design in relief by rotating the die and a soft steel roller under increasing pressure until the pattern has been transferred in relief to the softened steel roller. This mill must then be hardened and tempered. The actual engraving of the printing rollers is done by placing the hardened mill against one end of the roller and revolving them while

¹ Henri Clouzot, *Painted and Printed Fabrics*, p. 22. Copyright, 1927, by the Metropolitan Museum of Art.

sufficient weight is added to cut the design into the circumference of the roller. The mill is then moved along the roller so as to engrave a second repeat of the design.

This method entails great accuracy in the preparation of the die, which must be the exact size of the mill and also of the engraved roller, which must be the exact circumference or a multiple of the circumference of the mill.

The photographic process of engraving the copper roller is a recent development. By this method the time required to engrave a roller is reduced to one-tenth and the cost is reduced accordingly.

The advantages of roller printing are its high productivity, as a thousand or more yards are printed in one hour; the wide variety of design which can be handled by this method; and the accuracy with which each portion of an elaborate design may be fitted into a perfect whole. One disadvantage that may be noted is that the size of the roller limits the size of the design.

The "Duplex" or "Reversible" machine prints both sides of the fabric. It is really two machines combined into one. One side of the cloth is presented to one machine to receive the design. It then passes to the other machine where the reverse side is given the same design in such a way that the pattern on the two sides coincides.

A recent development in the printing of textiles is by the use of pigments as discussed in Unit Four. Most types of design are successfully printed with pigment dyes except very large ones.

Roller printing styles. There are three variations in roller printing known as *styles*. These are *direct* or *application style*, *discharge style*, and *resist* or *reserve style*. In the direct style of printing the dye is stamped directly from the roller onto the fabric in the form of a design. The ground may be stamped in color and the design remain undyed. This style may be recognized, as the dye usually shows less plainly on the wrong side.

The discharge style is one of the most important processes used today, being suited to every type of design. In this proc-

ess the entire fabric is dyed one color in the piece, and a discharge substance is printed in design on it. Its application affects the destruction or discharge of certain portions of this color.

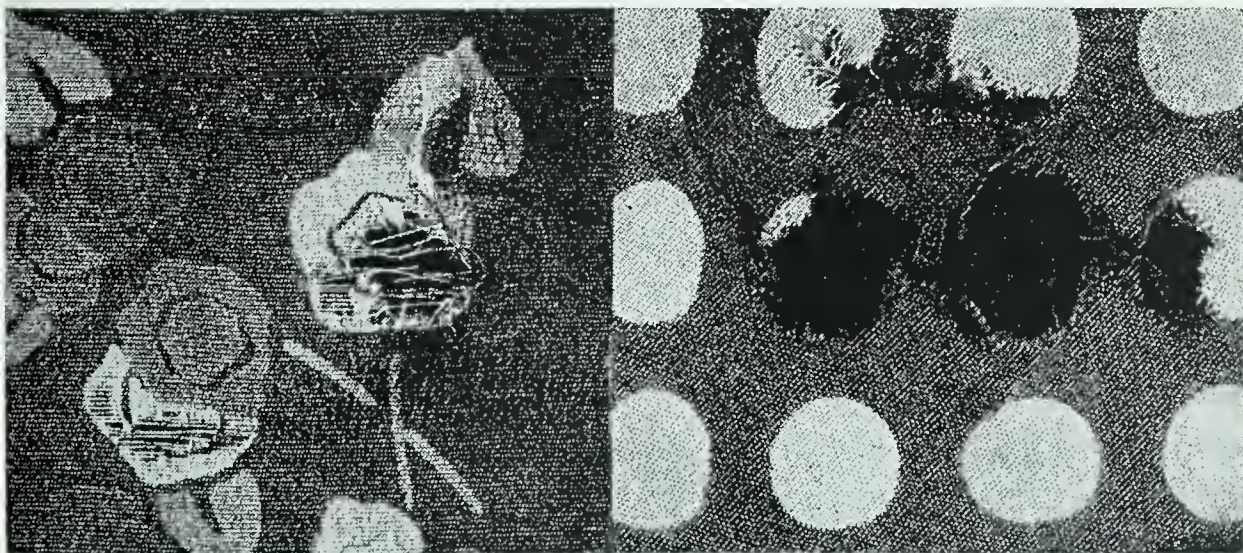
Reducing agents are the substances most often used to destroy the dye and thus permit the development of a pattern. The design is often in white on a dark background or in a lighter value of the background color, but it may be

brought out in a different color as well. The discharge paste may carry dyes the color of which is not affected by it. Thus one or many colors may be applied in the same operation that removes the ground color. Better effects are possible by the use of this style than by any other, but in some instances the substances applied to discharge the dye weaken the fabric so that the material falls into holes. (See illustration below.)

If white is a part of the design it is necessary that the fabric be carefully and thoroughly bleached before dyeing in order that by discharging the dye a white is produced. In some



Direct print.



Discharge print.



Simple "tie and dye" design, produced by process printing. The inset shows fabric tightly wrapped with cord in preparation for dipping in the dye vat. (The tie and dye process is discussed on page 157.)

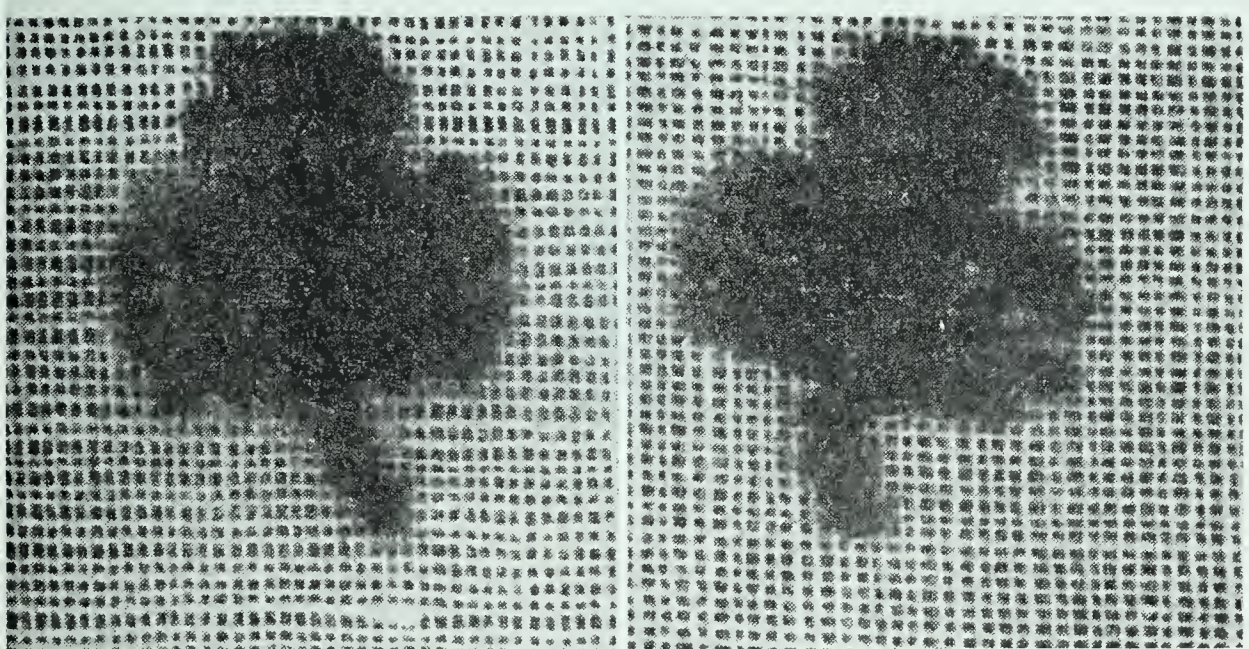
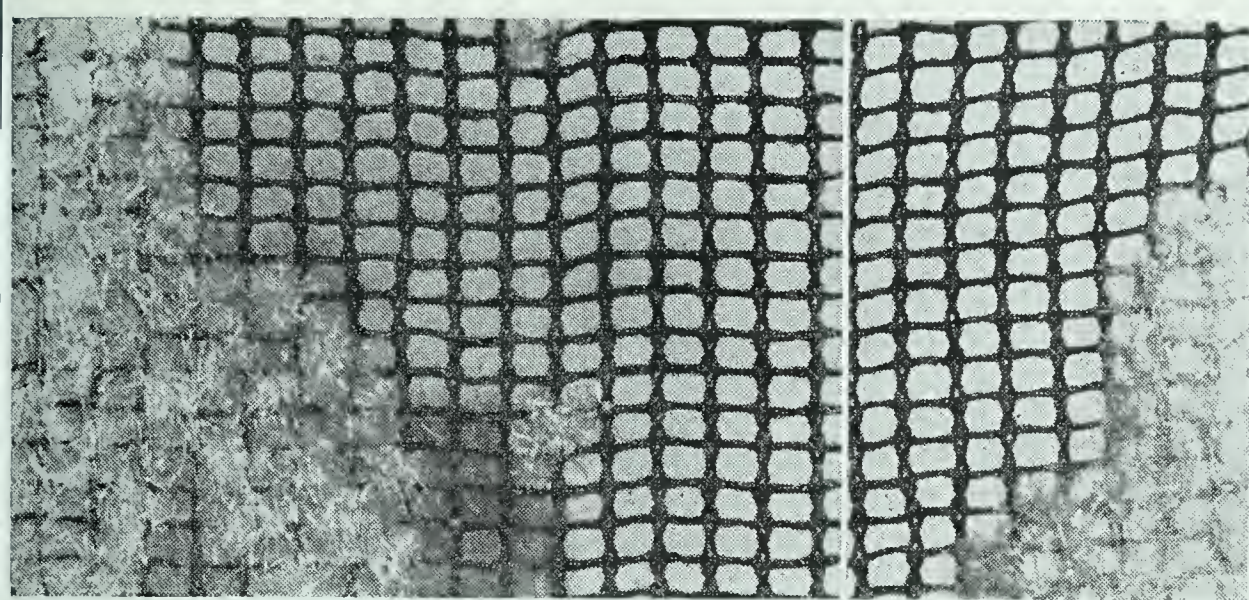
instances the white portions are printed with white pigments.

In order to discharge ordinary types of dyes, all that is necessary is to print on a thickened solution of a reducing agent, dry, age, and wash off. The three main types of dye-stuff used are direct, diazotized, and azoic. A direct dye used for the ground color is easily discharged as described above. However, to remove the diazotized dyes, a stronger solution of discharge is required together with an alkali and catalytic body. In all but the cheapest fabrics where color is added with the discharge paste, vat dyes are used for this purpose.

The resist or reserve style consists of covering portions of the fabric with substances that prevent the coloring of those parts. The action may be mechanical in that the material added does not allow contact with the dyestuff, or it may be chemical and destroy the dye or not permit its forming.

It is often difficult to determine whether a design has been produced by the discharge or the resist style.

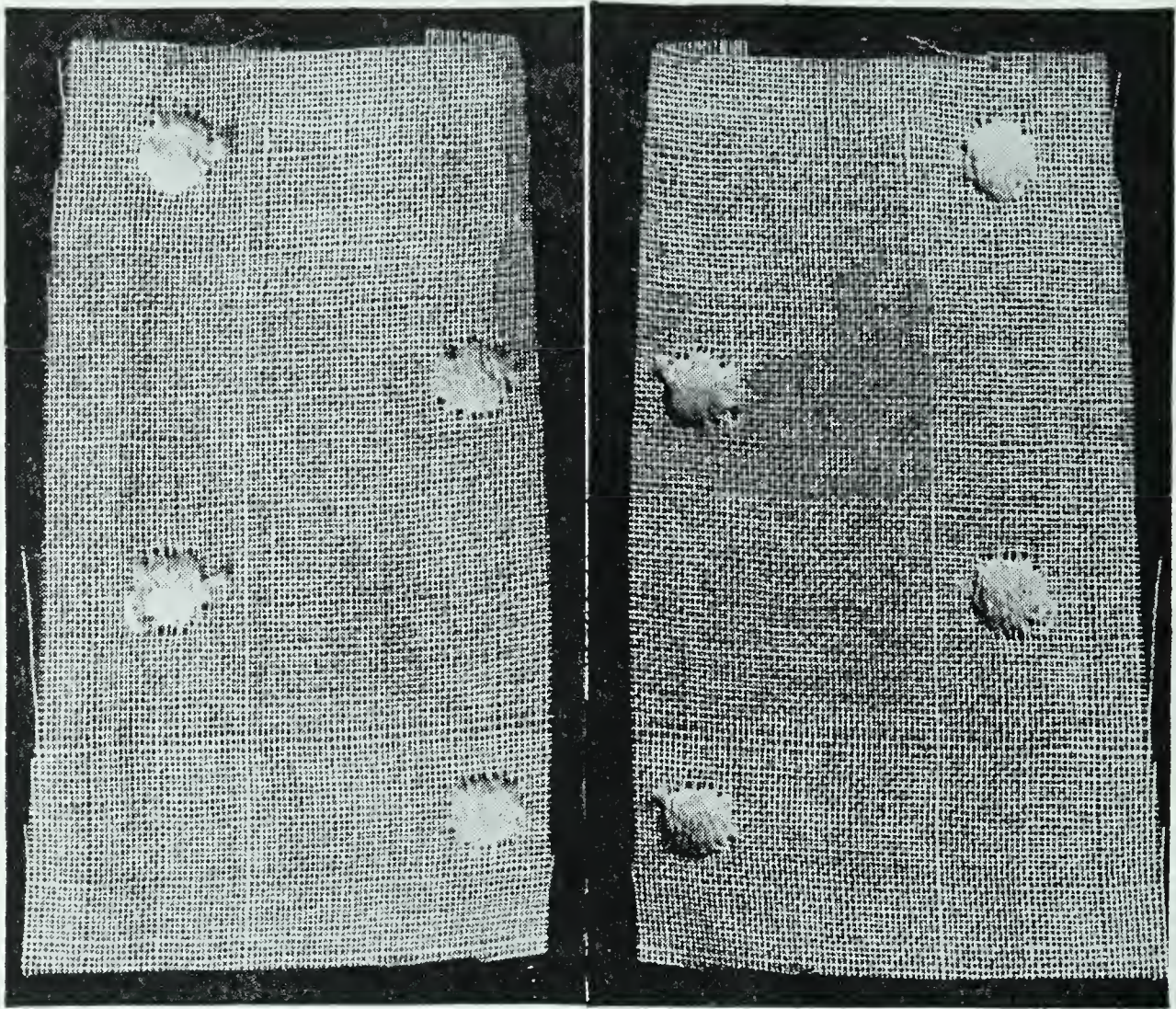
In early times design was produced on fabrics by means which today might be classed under one of these three styles of printing.



Two fabrics in which the design was produced by pressing and enmeshing finely cut fibers on cloth in a pattern. Note that almost as much cut fiber appears on the wrong side as on the right. (The illustrations at left show the right side.)

Batik. Batik is an ancient form of resist dyeing that is still in use today. In Java, noted for its beautiful batik, the work is usually done on cotton, but occasionally silk fabric is used. The material is carefully prepared to obtain its characteristic rich, clear color and soft texture. In the production of batik the entire design is drawn or stamped upon the fabric.

Both the face and the back of the portion to remain undyed are covered with a thin layer of melted wax and the fabric is



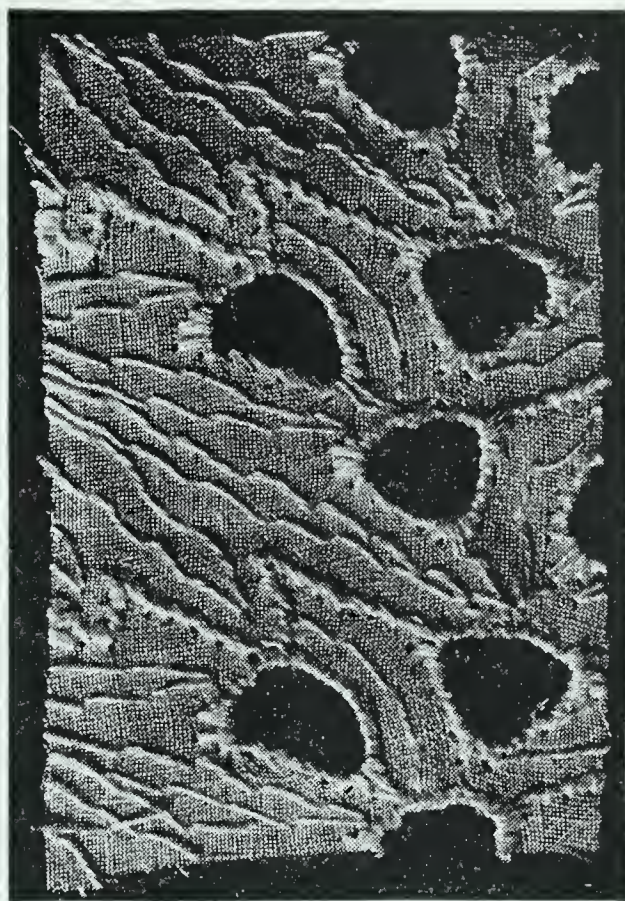
Left, back of surface design produced by embroidery; right, face of fabric.

then piece dyed. The Javanese remove the wax after every dyeing and each time cover all of the material to remain undyed. In Europe and America one color is dyed over another and the wax is not removed until the piece is finished. After the first dye is dry the melted wax is applied to those parts to remain the present color, and the fabric is again dipped in the desired dye. The fabric must be dyed the lightest color first and so on through the succeeding processes, for the parts carrying the last color to be applied have necessarily been exposed to each dye bath and must be covered by the last. Batik is used mostly on textile fabrics but may be used on all types of material that can be impregnated with dye. This hand process furnishes an inexpensive means for decorating scarfs or other small articles.

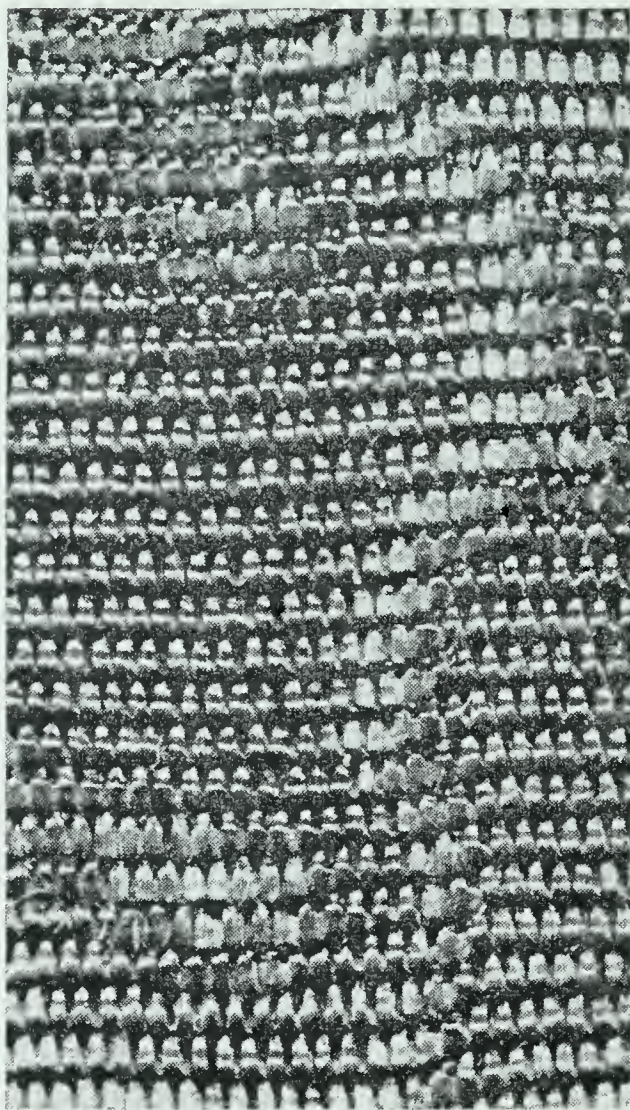
Another form of resist style is the *tie-and-dye process* which is based upon the principle that liquids penetrate in proportion to the looseness of the folds of the cloth. Different portions of a fabric are wrapped with thread in order to hinder but not to prevent the absorption of the dye. (See page 154.) The entire fabric is then dipped into the dye bath. When the wrapped parts are unfastened it is found that the dye has penetrated irregularly, thus forming a design with no distinct outline. Different colors may be applied by successive dyeings. Batik and tie-and-dye are both hand processes by which originality may be obtained in textile design.

Other methods by which surface design is produced. Although by far the greater portion of surface design is produced by adding dyestuffs to the surface of the fabric, some fabrics are decorated by means of embroidery, moiré, or by applying dots or figures of different materials to which finely cut fibers may or may not have been added.

This method is sometimes spoken of as applique because the figure is raised above the surface of the cloth. (See page 156.) The figure may be of any substance, not removed by cleaning, that can be applied by means of perforated stencils. A recent development is the Electro-Fiber-Coated fabrics. The adhesive-coated fabric is pulled through an electrostatic field and short fibers are carried on a conveyor belt between two electrodes. The fabric passes close to the field and the fibers are propelled onto the fabric in such a manner that they are at right angles to the cloth. By this



Eyelet embroidery illustrating a type of surface design.



Photograph of moiré fabric showing clearly the patterned effect.

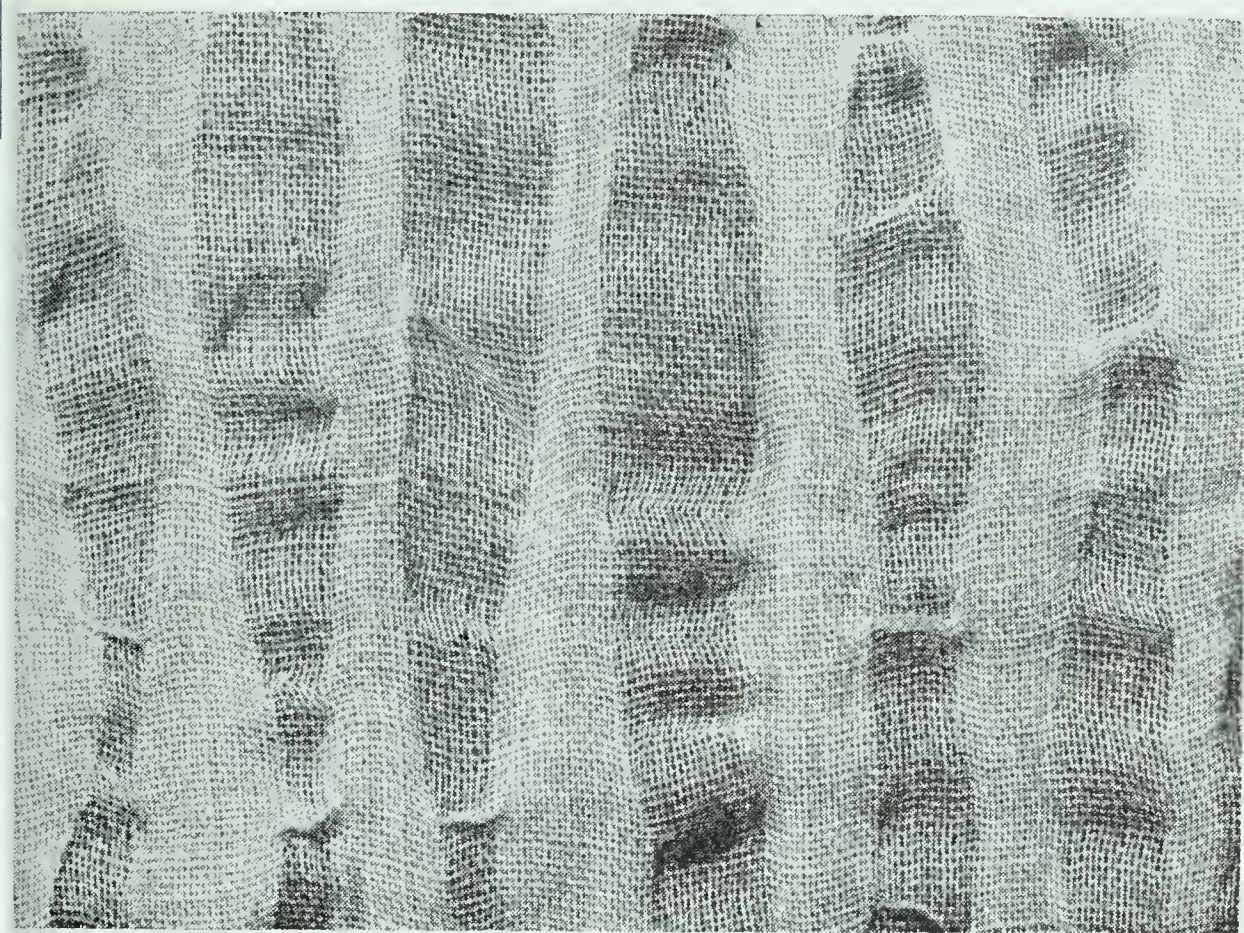
moiré fabrics. Flattening of the yarns causes a variation in the reflection of the light, thus giving the desired result. This process is seldom to be recommended in cotton, as it is destroyed by washing. The moiré effect is comparatively permanent in silk, and is usually satisfactory. When applied to cellulose acetate rayon, moiré is guaranteed to be permanent to dry cleaning, laundering, or steaming provided the temperature is not raised above 270° F.

Because of the nature of its structure, velvet lends itself to still another type of surface design. By means of a modification of the resin treatment given pile velvet to make it noncrushable, the "lie" of the pile is set as desired, and thus a pattern effect is produced due to the difference in the manner in which the light is reflected. In one method the pile is

method a fabric in stripes or figures of short pile can be prepared. In fact, there seems to be no limit to the processes or combinations possible.

Hand or machine embroidery is a popular means of decorating fabrics. In the machine product the design is often in an all-over pattern of eyelet embroidery, or it may be in the form of a small design. (See the illustration on page 157.)

A moiré process in which a design is produced in a patterned effect is the result of flattening the yarns by a special form of pressing. (See page 158.) A rep material in which a coarse filling yarn gives a corded effect is generally used for



Plissé fabric. The crepe effect is produced by chemical treatment.

impregnated with a solution of resin, then mangled and dried. Just before it is dry, the pile is brushed so as to stand upright, then pressed with a roller with a design that is deeper than the pile. When completely dried, the resin hardens, and the light reflected differently from the flattened pile gives a pattern effect. Or the back may be sprayed with a limited amount of soluble resin which flows down the pile; the pile is then brushed in different directions, dried, and baked.

Plissé crepes, sometimes called seersuckers, are produced in the finishing by the shrinking action of caustic soda. The fabric may be printed in a stripe with a gum resist, and then run through a bath of caustic soda which shrinks the parts not treated with the gum. The puckering of the parts not protected forms a crepe effect. A direct method of obtaining this effect consists of printing the fabric in a stripe with caustic soda, which causes the fabric to shrink and the unprinted part to pucker into a crepe effect. Fabrics in which the design is

obtained in either of these ways should not be ironed in laundering. If the fabric has been given a permanent organdy finish before creping, both the crispness and the crepe effect are permanent.

Embossed crepe effects are produced by means of engraved rollers. Heat and pressure serve to set the crepe effect in the cloth. However, this type of crepe is not permanent to laundering.

Suggestion for the Laboratory

Study fabrics illustrating various methods of producing surface design. What effect does the design have on the service qualities of the cloth?

REFERENCES FOR ADDITIONAL STUDY

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Section Two

THE TEXTILE FIBERS



Unit One

TEXTILE FIBERS: THEIR CLASSIFICATION AND ESSENTIAL PROPERTIES

MOST methods of fabric construction necessitate the formation of the fibers into a continuous strand or length, known as yarn. Therefore, to be used as a textile fiber, it is important that the filaments possess sufficient length, strength, and cohesiveness to permit them to be made into a continuous strand suitable for fabric construction. Together with length and strength the fiber must be fine enough to allow the construction of a yarn of desirable size and weight. As most household and clothing materials are comparatively fine and light in weight, the number of fibers that can be utilized is limited. A harsh fabric is not suitable for clothing; therefore a textile fiber for this use must be soft and pleasing to the touch.

Pliability is essential in textile fibers in order that they may be wrapped one around another in the formation of yarn. Elasticity is a property closely related to pliability and adds greatly to the value of a fiber.

It is necessary that a fiber possess the ability to absorb liquids readily in order that it may be bleached or dyed. Except for this property of fibers, man's clothing would have lacked its color possibilities. The comfort with which fibers can be worn next to the body depends greatly on their ability to absorb and give off moisture. The readiness with which a linen fabric takes up and gives off moisture causes it to feel cool. In contrast with this, wool absorbs moisture readily and gives off heat of absorption. Wool gives up moisture slowly, thus preventing chilling when it is worn. The extent to which

cloth can enmesh air, which is one of the best insulating agencies, determines to a great extent its value as a heat-retaining material.

Fibers differ in the ease with which they can be cleaned. Upon this property of fibers depends to a great extent their value for use in clothing and household fabrics.

Fineness and evenness of diameter, length, and luster are important properties of the fiber that determine the quality of the yarn made from it. Upon these and other properties of the fiber depend the desirability and the durability of textile fabrics.

A textile fiber must be commercially available; that is, the supply must be more or less constant and available in large quantities at a price which will permit it to be handled at a reasonable profit.

If a new filament is found possessing all of the properties given above, it is soon added to the list of commercial textile fibers—as the example of nylon has shown.

PROBLEM 1. HOW ARE TEXTILE FIBERS CLASSIFIED?

Some few filaments such as wool, silk, cotton, and linen possess in their natural state the properties necessary to permit their use in the production of fabrics. With the aid of science man has been able to produce new fibers, so we now have natural fibers and synthetic fibers. These groups are subdivided, according to their source and their chemical composition, into animal, vegetable, and mineral fibers, and organic and inorganic fibers.

A classification of the most important fibers used in the textile industries follows:

CLASSIFICATION OF TEXTILE FIBERS

According to source and chemical combination

A. Natural fibers

I. Animal

1. Hair fibers—sheep's wool, mohair, camel's hair, alpaca, vicuna, llama
2. Cocoon fibers—silk

- II. Vegetable
 - 1. Seed hairs—cotton, kapok, milkweed
 - 2. Bast fibers—flax, hemp, jute, ramie
 - 3. Leaf fibers—abaca (Manila hemp), pineapple fiber
 - 4. Wood fibers—redwood
- III. Mineral
 - 1. Asbestos
- B. Synthetic fibers
 - I. Organic
 - 1. Cellulose base
 - (a) Rayon
 - (1) Regenerated—viscose, cuprammonium, nitro-cellulose
 - (2) Cellulose derivatives—cellulose acetate
 - 2. Protein base
 - (a) Animal—casein
 - (b) Vegetable—peanut, soybean, cornmeal
 - 3. Resins
 - (a) Polyamid, nylon
 - (b) Vinyl—velon, saran
 - (c) Vinylchloride—vinyon
 - 4. Miscellaneous
 - (a) Alginate fibers
 - (b) Plastics
 - (c) Coated yarns
 - II. Inorganic
 - 1. Silicates—glass
 - 2. Metals—gold, silver, copper, aluminum

The relative importance of these fibers in the textile industry is shown in the tables on page 166.

The consumption of textile fibers was the lowest in 1945 of any year since 1940 but was high in comparison with pre-war years. All of the decline in consumption, 1945, occurred in cotton, which is about five per cent below 1944 figures, 13 per cent below 1943, and 19 per cent below 1942.¹

The classification of textile fibers as natural and synthetic has been the subject of controversy for some time. Certain authorities contend that there are no natural textile fibers,

¹ *Textile World*, Vol. 96, No. 2 (1946), p. 102.

WORLD PRODUCTION OF FOUR TEXTILE FIBERS ¹

YEAR	MILLIONS OF POUNDS					PER CENT OF TOTAL				
	Cotton	Wool	Silk	Rayon	Total	Cotton	Wool	Silk	Rayon	Total
1937	17,600	2,280	121	1,824	21,825	81	10	1	8	100
1938	13,200	2,340	123	1,951	17,614	75	13	1	11	100
1939	13,100	2,460	123	2,300	17,983	73	13	1	13	100
1940	13,700	2,500	127	2,463	18,790	73	13	1	13	100
1941	12,500	2,540	115	2,759	17,914	70	14	1	15	100
1942	12,750	2,490	80	2,750	18,070	71	14	—	15	100
1943	12,800	2,450	50	2,633	17,933	71	14	—	15	100
1944	12,350	2,300	30	2,156	16,836	73	14	—	13	100

¹ *Rayon Organon*, Dec. 1945, p. 189.

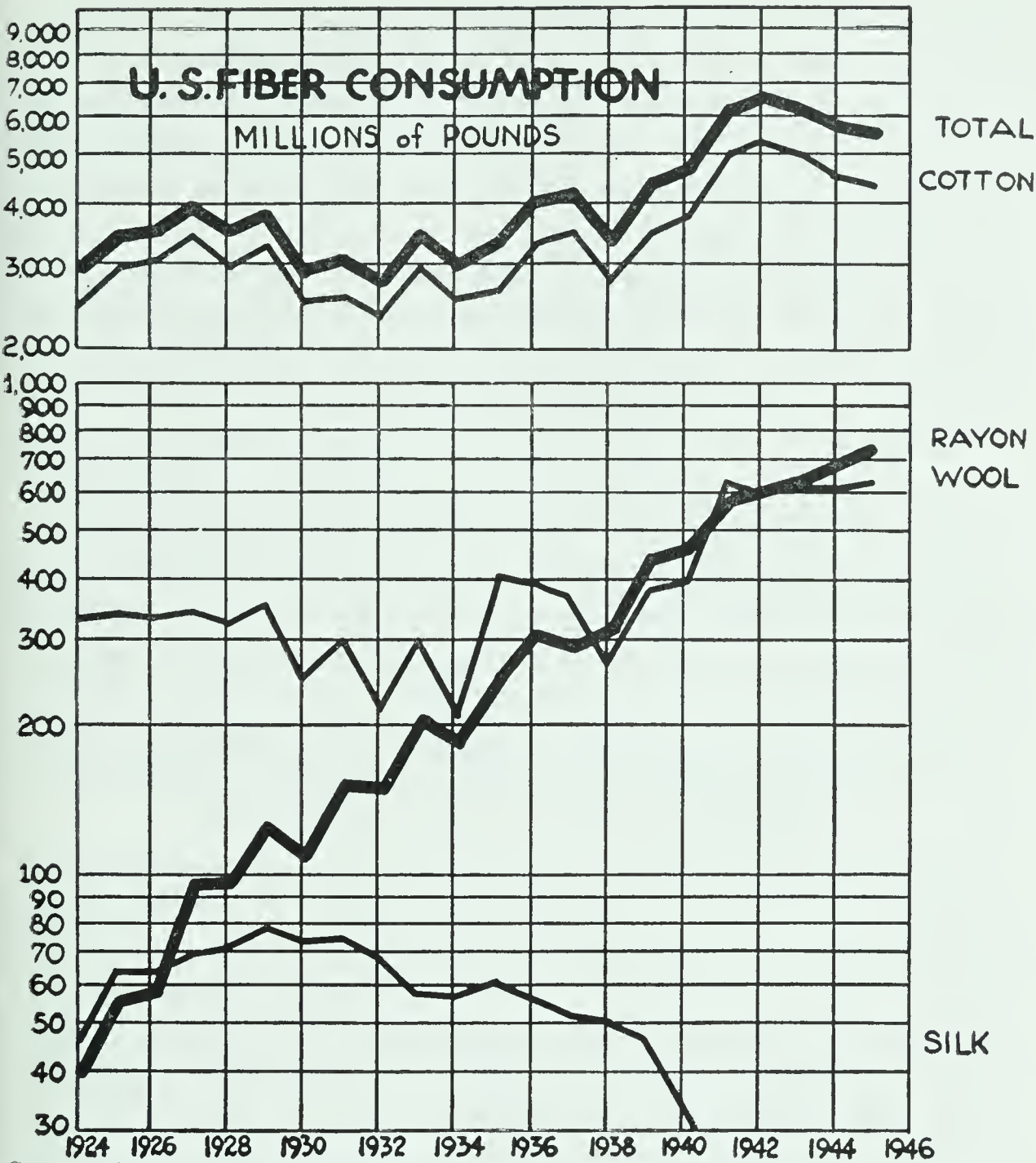
U. S. FOUR-FIBER CONSUMPTION ²

YEAR	MILLIONS OF POUNDS					PER CENT OF TOTAL				
	Cotton	Wool	Rayon	Silk	Total	Cotton	Wool	Rayon	Silk	Total
1936	3,470.2	406.1	322.4	57.8	4,256.5	81.5	9.5	7.6	1.4	100
1937	3,657.1	380.8	304.7	53.6	4,396.2	83.2	8.7	6.9	1.2	100
1938	2,918.7	284.5	329.4	51.7	3,584.3	81.4	7.9	9.2	1.5	100
1939	3,629.7	396.5	458.8	47.3	4,532.3	80.1	8.8	10.1	1.0	100
1940	3,953.6	411.1	482.0	35.8	4,882.5	81.0	8.4	9.9	0.7	100
1941	5,187.3	653.2	591.8	23.4	6,454.7	80.3	10.1	9.2	0.4	100
1942	5,636.7	613.8	620.8	5.0	6,876.3	82.0	8.9	9.0	0.1	100
1943	5,269.0	628.0	656.1	1.4	6,554.5	80.4	9.6	10.0	—	100
1944	4,792.4	623.9	704.8	0.6	6,121.7	78.3	10.2	11.5	—	100
1945	4,508.2	648.2	769.9	0.5	5,926.8	76.1	10.9	13.0	—	100
1946	4,844.9	748.4	875.4	6.3	6,475.0	74.8	11.6	13.5	0.1	100

² *Rayon Organon*, March 1947, p. 38.

there are only natural fibers that have been selected by man for use in textiles. They point out that those fibers chosen by man and improved by selection and breeding were produced by nature for purposes far different from those for which they are used in the construction of textiles.

For example, a furry or woolly coat of hairs or fibers has been provided as a protection for sheep and other animals. The caterpillar spins threads of silk which it forms into a shell or cocoon in which to change into a moth. In the



U. S. fiber consumption.

vegetable kingdom from which man obtains the bulk of fibers to be used in textiles, fibers are produced for a wide variety of purposes. Kapok and milkweed fibers serve as a means of carrying the seeds, and cotton is believed to have been produced to prevent dehydration of the seeds. The bast and leaf fibers form a part of the skeletal structure of the plant, giving it rigidity. A.S.T.M.¹ lists over 100 different

¹ American Society for Testing Materials.

natural fibers as of commercial importance and to these we must add the fibers that man has created. However, little more than a dozen of these have importance in fabrics for industrial, household, and clothing use. Listed in importance of the quantity produced, textile fibers are cotton, jute, wool, rayon, flax, ramie, and silk.

An examination of the classification of fibers as given on pages 164 and 165 shows that the natural fibers fall into six groups, namely, hair fibers, cocoon fibers, seed hairs, stem fibers, leaf fibers, and one mineral fiber.

It has been little more than fifty years since man first created fibers specifically for use in textiles. The first attempts were in imitation of the natural fiber silk which was the most expensive fiber and possessed many desirable qualities. At first the man-made fibers were known by the term 'artificial silk,' but this was replaced by the term 'rayon.' Acceptance of this term for all man-made fibers of a cellulose base removed the stigma of artificiality and acknowledged the acceptance of these fibers as an extra group to be evaluated on their own properties.

During this period the term 'synthetic' was accepted interchangeably with 'man-made' to distinguish these fibers from natural fibers. However, with the production of new fibers which were truly synthesized from raw materials chemically different from the finished product, the use of the term synthetic to include fibers in which the chemical composition was not changed was questioned.

However, no satisfactory term has been found to replace synthetic as the classification of man-made fibers so it is again being widely accepted to include all fibers not found in their finished state in nature.

Each fiber, whether natural or synthetic, is made up of high polymers or giant chain molecules which are lined up more or less parallel to its axis. As the more important properties of a yarn are dependent on the staple length, orientation, twist, and chemical properties of its fibers, so the properties of a fiber depend on the length, orientation, and chemical nature of its constituent molecules. The properties of the

constituent molecules include the properties of the simple units which build up the molecular chain as well as those properties which hold these units into chains, and the chains in bundles.

The two main classes of fibrous material are the carbohydrates and the proteins. The chemical behavior of the cellulose fibers is largely due to the presence of the glucose unit with its alcoholic groups, and the behavior of the protein fibers is largely due to the presence of the amino group. The basic nature of the amino group has a tendency to counteract the acid properties of the carboxyl group which is also present. Proteins are therefore amphoteric in nature.

A classification of the fibers according to their chemical composition is a great aid in their study. An understanding of some of the reactions characteristic of the group is necessary in order to handle intelligently fabrics made from them.

PROBLEM 2. WHAT ARE THE CHARACTERISTIC REACTIONS OF PROTEIN FIBERS?

Inasmuch as protein is a primary constituent of all animal tissue and is essential to its growth, we are not surprised to find that both of the natural fibers, wool and silk, are protein substances. The synthetic protein fibers sometimes classified as Protan fibers are from both animal and vegetable sources. The most important one from an animal source is produced from the casein of milk. Soybeans, corn, and peanuts furnish proteins for the production of fibers more or less important in the textile field. Many other sources have supplied protein fibers which are still in the experimental stage.

These fibers differ greatly in their physical structure but are quite similar in chemical composition and give typical protein reactions. Therefore, a study of the chemical reactions of the proteins will aid in further understanding the natural protein fibers and their properties, as well as the synthetic fibers made from a protein base.

Proteins are complex compounds of high molecular weight,

composed of carbon, hydrogen, oxygen, and nitrogen. Sometimes small amounts of other elements, particularly sulfur and phosphorus, are also present. Most proteins are composed of but a few elements, the relative proportions of which vary within narrow limits.

	PER CENT ¹
Carbon.....	50-55
Oxygen.....	19-25
Nitrogen.....	15-19
Hydrogen.....	5-8
Sulfur.....	0-5
Phosphorus.....	0-1
Other elements.....	0-1

¹Porter C. W., *The Carbon Compounds*, Rev. Ed., p. 192, Ginn and Co.

Protein when burned gives off a characteristic disagreeable odor similar to that of burning feathers. This is due chiefly to the presence of nitrogen in the compound; an odor of ammonia upon ashing or an alkaline reaction of the vapor (the formation of a blue color) when tested with moist litmus paper is further proof of the presence of animal tissue.

Wool fibers do not support a flame and the ash forms into a firm but crushable black bead or ball. Aralac does support a flame, otherwise burning similar to wool.

Unweighted silk spits and sparkles as it burns and the ash forms as soft crushable beads, often on the end of each yarn. Heavily weighted silk does not burn but chars and retains the form of the material. Often the weave is clearly visible. When protein fibers are burned in a test tube, the formation of drops of water on the sides of the tube indicates the presence of hydrogen and oxygen, and the carbon is found as a charred residue.

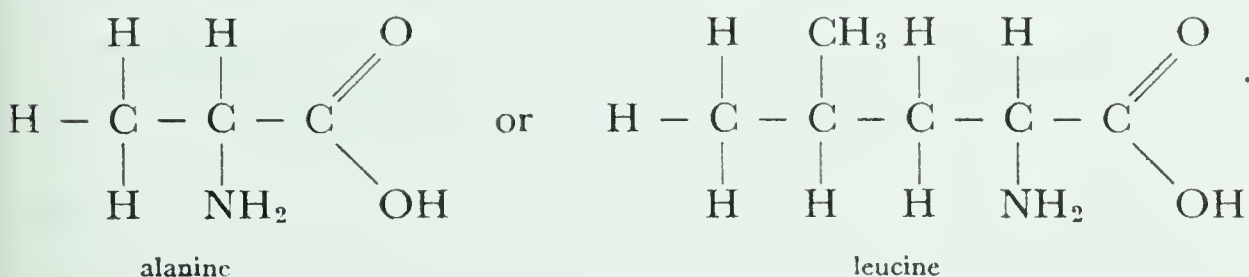
Proteins found in wool and aralac fibers always contain slight traces of sulfur; therefore, in addition to the above reactions, wool and aralac fibers when heated in a test tube give off fumes of H_2S . These fumes in the presence of lead acetate produce lead sulfite which is recognized as a brown deposit. Therefore, if a filter paper moistened with lead acetate is held

in the fumes of burning wool or aralac a brown deposit is formed. This test has been used to detect the presence of wool fibers, but now that the casein fibers and animalized fibers respond in the same way, the validity of this test is nullified.

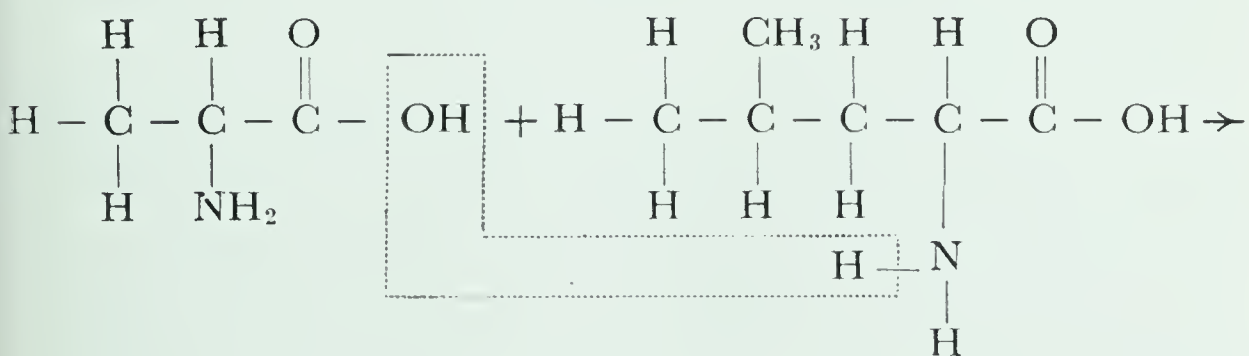
Proteins present in the natural fibers or used in the production of synthetic fibers are insoluble in hot or cold water but are injured by the continued action of boiling water. There is ample proof of the presence of amino acids, typical of the protein group, in the composition of both silk and wool. Protein fibers are amphoteric in nature; that is, they have the properties of both acids and bases. The presence of the NH_2 group, which has characteristics similar to ammonia, gives protein its basic properties; and the presence of a $-\text{C}=\text{O}$

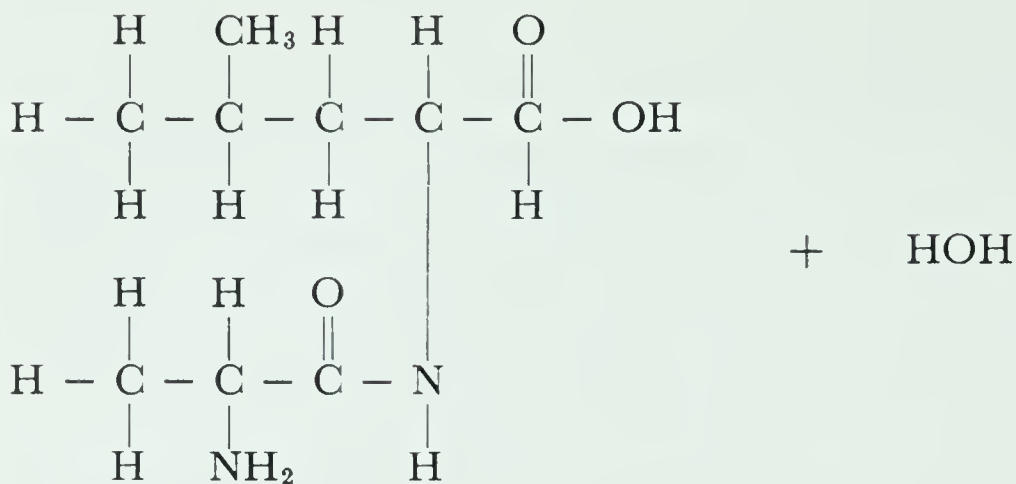


which is an acid group, gives the protein its acidic characteristic. Long chains of α -amino acids, such as



combine together in the following manner through their amino and carboxyl groups (peptide linkage) to form proteins:





This product in turn may combine with another molecule of α -amino acid; by continued linking of α -amino acids in this manner the complex proteins are formed.

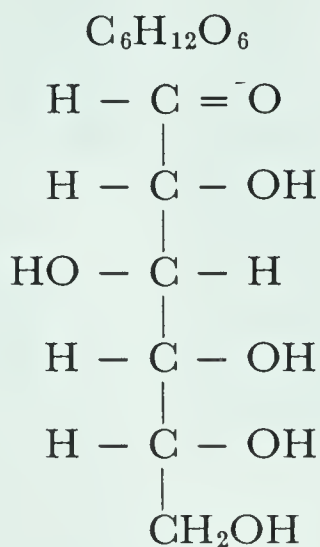
Protein fibers are easily destroyed by concentrated mineral acids. However, the specific reactions of dilute acids with these fibers are the bases of many of the dyeing and finishing processes. Under ordinary conditions alkalies have a decidedly injurious effect on animal tissue.

PROBLEM 3. WHAT ARE THE CHARACTERISTIC REACTIONS OF CELLULOSE FIBERS?

An understanding of the vegetable fibers, cotton, linen, and the rayons, requires some understanding of cellulose, the principal constituent of plant cells. Cellulose $(\text{C}_6\text{H}_{10}\text{O}_5)_x$ is a complex compound made up of carbon, hydrogen, and oxygen. The pattern produced by X-ray diffraction indicates that the so-called crystal unit of cellulose which is repeated regularly throughout the cellulose structure is composed of glucose residues.

The manner, therefore, in which carbon, hydrogen, and oxygen are combined in cellulose differs from that in which they are found in proteins. These elements in cellulose are united in the form of $(\text{C}_6\text{H}_{12}\text{O}_6)_x$, or glucose residues. The glucose molecule is composed of carbon atoms linked together and having hydrogen atoms and OH (or alcohol) groups attached to them.

Formerly glucose molecules were considered to have a straight chain structure represented as follows:

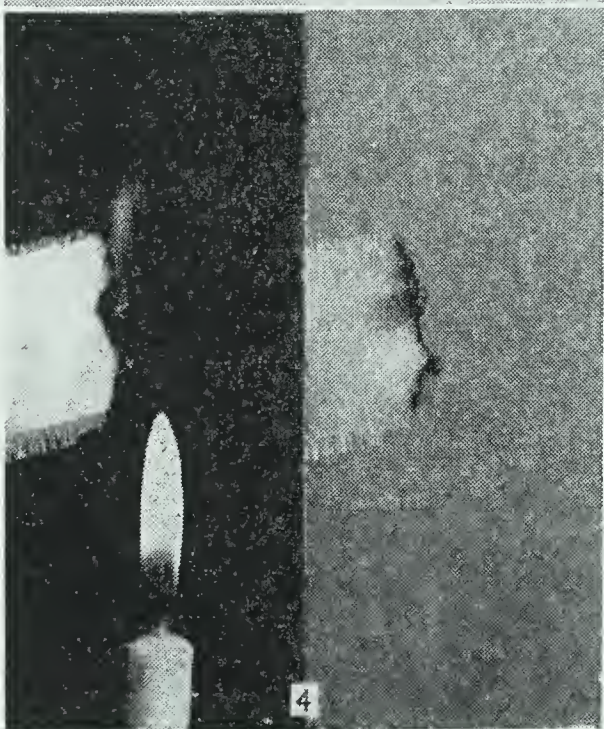
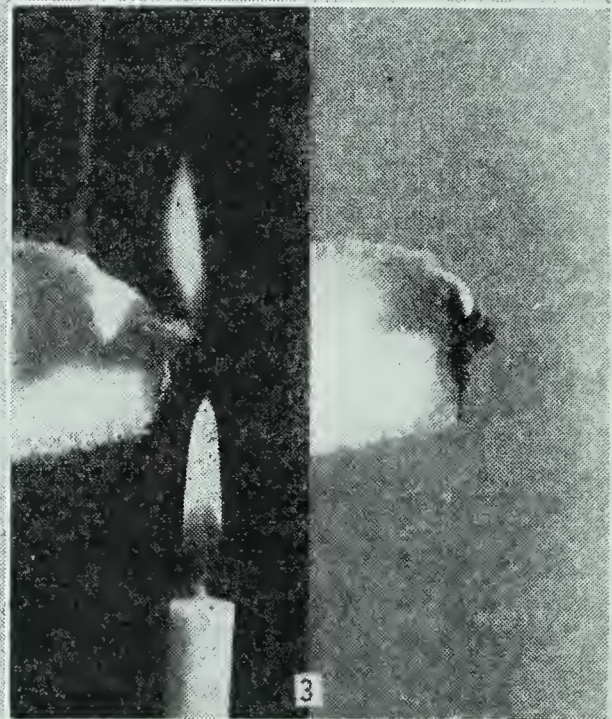
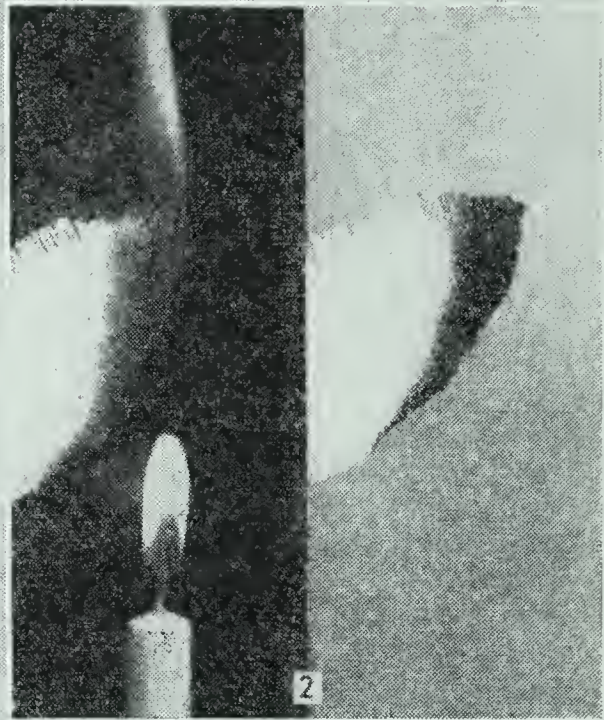
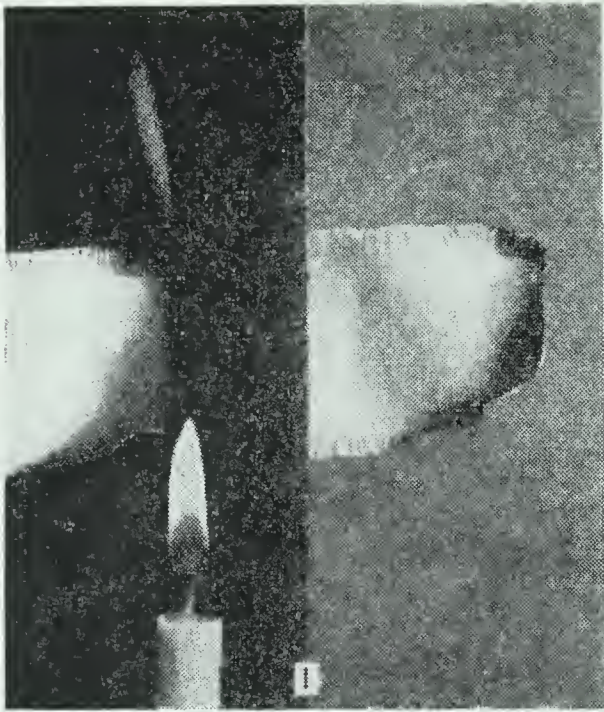


The modern theory of the structure of glucose presents the molecule as having one of two tautomeric arrangements of either the aldose or the hetrocyclic six-membered ring formation. Glucose, as the building block of cellulose, is present at the ends of the larger cellulose molecule as an aldose group and as the hetrocyclic ring formation. Both forms may be found in the body of the cellulose molecule. The condensation of two glucose molecules with the elimination of one molecule of water yields a molecule of cellobiose.

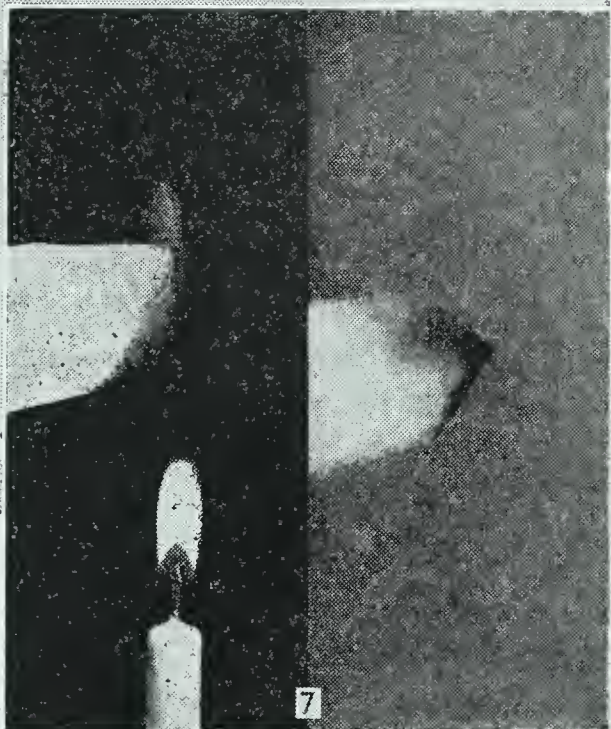
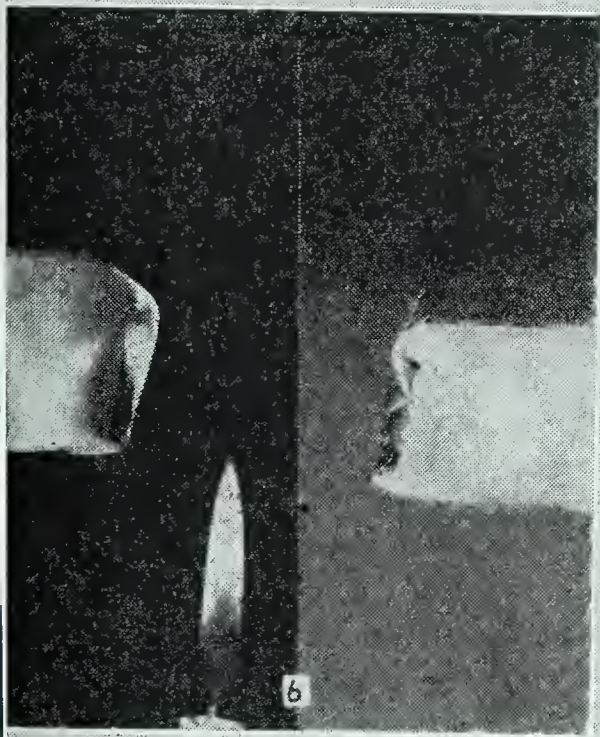
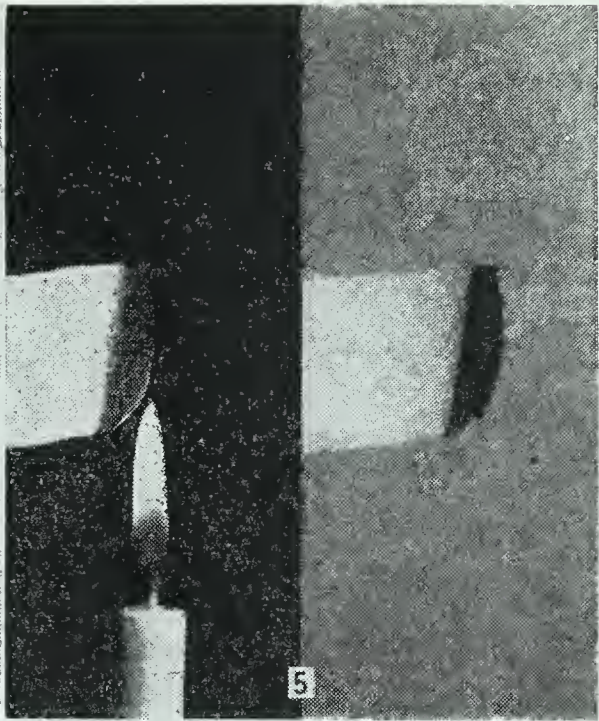
Linkage similar to that represented in the structure of the cellobiose molecule is found in the polymerization of the many glucose molecules that go to make up a molecule of cellulose. Here the cellulose units are linked through the "oxygen bridge" to form long chains of the cellulose molecule.¹

To give some idea of the length of the cellulose chain, Harworth and Meachemer calculate that there are from 100 to 200 anhydro glucose units in each cellulose molecule. The end sections of the glucose molecule are tautomeric with each other, even as are the glucose molecules from which the larger units are built. These chain cellulose molecules are held together in groups of ten or more to make a bundle visible un-

¹ Courtesy H. R. Mauersberger and E. W. K. Schwarz, *Rayon and Staple Fiber Handbook*, Third Edition, p. 66.



As shown above and on the opposite page, the burning test may be used to identify some of the textile fibers. (1) Cotton, (2) linen, (3) wool, (4) pure dye silk.



(5) Weighted silk, (6) cellulose acetate rayon, (7) viscose rayon.

der the microscope. The bundles unite to form fibrils, and these in turn combine to form the cellulose textile fibers.

Cotton, linen, and regenerated cellulose rayon burn readily in the air without noticeable odor and leave only a small amount of soft, fluffy ash, which is easily distinguishable from the firm, black substance left from the burning of protein. (See the illustrations on pages 174 and 175.)

The flame of burning cellulose is difficult to extinguish and the smoldering, smoking material often bursts again into a flame. The smoking and smoldering after the flame has been extinguished is considered proof that the material is cellulose. When burned in a test tube the formation of drops of moisture indicates the presence of hydrogen and oxygen and the carbon remains as a small amount of residue.

The cellulose of cotton, linen, and rayon is comparatively resistant to the action of alkalies but is destroyed by concentrated acids. The specific reaction of various acids and alkalies under controlled conditions is made use of in the finishing of materials containing cellulose.

The reaction of cellulose with mineral acid is the basis of the process known as the carbonization of wool. In this process under controlled conditions the acid destroys the cotton and affects the wool but slightly.

The natural vegetable fibers, linen and cotton, although more resistant to chemical reactions than most cellulose fibers, are injured when exposed to light and air for some time. They are also affected by the action of oxidizing agents.

For further information concerning identification of fibers see the appendix, pages 580–583.

Cellulose from wood pulp or cotton, dissolved in various reagents, is the substance used in the production of the rayon fibers. Rayons, although made from cellulose, chemically belong to two groups: regenerated cellulose, and cellulose derivatives. The first group includes the fibers made by three processes—the viscose, the nitrocellulose, and the cuprammonium. Being regenerated cellulose, they react chemically as other cellulose. (Section Two, Unit Six.) Fibers made by these processes burn readily in the air the same as cotton and

linen, and the ash remaining is typical of cellulose. However, when burning they may be distinguished from natural cellulose fibers by a slight chemical odor. Rayon of the second group made by the cellulose-acetate method is a cellulose derivative and therefore reacts quite differently chemically from the other rayons. When brought near a flame this type of rayon fuses or melts, forming a black, hard, not brittle ash. Instead of forming brittle beads as does silk, cellulose-acetate fuses and drops as melted metal. (See illustration page 175.)

PROBLEM 4. WHAT ARE THE CHARACTERISTIC REACTIONS OF SYNTHETIC RESIN FIBERS?

The recent rapid development of synthetic resins as the raw material for new synthetic fibers and also for their broad application in the finishing of fabrics makes necessary some study of these compounds.

As early as 1664 Robert Hooke suggested the possibilities of synthetic fibers. But while the use of resins was mentioned at this time, their development was much slower than that of the rayons. In 1734 Reamur, the French naturalist, made the following suggestion: "Silk is only a liquid gum which has been dried; could we not make silk ourselves with gums and resins?" Natural resins, however, were found to be unsuited to be drawn or spun into useful textile fibers. Within the past few years a new group of high molecular protein-like compounds, commonly classed as synthetic resins, has been produced and rapidly brought into commercial production.

Synthetic resins as a class are "high molecular weight polymers" commonly spoken of as "high polymers." They consist of large molecules which are produced by the joining together of monomers. Molecules, the building blocks used by the chemical engineers in the construction of all synthetics, represent the union of particles or atoms. Polymers vary greatly in such physical properties as hardness, flexibility, and elasticity which may be controlled by varying the monomers used, but they possess certain properties in common, an important one being the ability to form a film. By mixing the monomers

before polymerization the chemist can produce co-polymers of varying characteristics as well as polymers.

The chemical reactions usually taking place in the production of synthetic resins are either addition polymerization or condensation polymerization. Most addition polymers such as the polyvinyl group are thermoplastic, that is, heat softening. The condensation polymers represented by the formaldehyde condensation products with phenol, urea or melamine, and the alkyd type are thermosetting, that is, heat hardening.

The development of synthetic resin fibers and also many of the new, permanent finishes which enhance the durability and characteristics of fabrics has paralleled the development of the chemistry of polymers.

Vinyon, a resin of the thermoplastic type, is a co-polymer of vinyl chloride (C_2H_3Cl) and vinyl acetate ($C_4H_6O_2$) produced by polymerization. The result of this combination is a straight chain or linear co-polymer of great length and consequently great molecular weight.

Saran, *Velon*, or *Permalon* is vinylidene chloride resin produced from ethylene and chlorine by polymerization.

Nylon is the family name for a resin of the polyamide type. A polyamide polymer is one containing a plurality of amide (NH_2NH) linkages. These polyamides are formed by the synthetic reaction of dibasic acid with an organic diamine. By this reaction small molecules (amides) are formed. These are changed by heating into the giant molecules or superpolymers. Nylon does not support a flame but melts into tiny hard balls pale green in color. It can be identified by this reaction.

Suggestions for the Laboratory

Identify as many fibers as possible by burning them in the air and in a test tube. Test the fumes with litmus paper.

Obtain current production and consumption numbers for all fibers. Discuss trends noted.

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Unit Two

WOOL AND OTHER HAIR FIBERS

THE origin of the use of the fiber covering of animals in the construction of clothing and household fabrics is not known, for it antedates the beginning of recorded history. Wool was no doubt the first fiber used by man as clothing. It was worn first in the form of a skin or pelt; later the fibers were matted or felted into a fabric which was more easily adapted to the varied needs of the people. The next step in its development was the formation of the fibers into yarns from which fabrics were constructed. Today the pelts of certain animals are used as furs; the loose fibers from other pelts are felted into cloth or are twisted into wool yarns to be braided, woven, or knitted into every type and variety of material.

An interesting story is sometimes told of the shepherd lad who twisted together a strand of wool fibers to bind around his bundle of fagots. This is cited as the beginning of the formation of short fibers into yarns from which cloth could be constructed.

As we all know, wool, the soft fiber covering of sheep, is the most important animal fiber used in clothing and household fabrics. Fibers and hairs of other animals also are used in construction of cloth. These specialty hair fibers, as they are sometimes called, are becoming increasingly important for use in staple as well as in novelty fabrics.

The importance of wool as a textile fiber is shown by the fact that it was not only one of the first fibers made into material for clothing and household use, but that it remains the fiber most suitable for tailored garments and many household fabrics. The world's production of wool has declined slightly

since 1941 as shown by the table on page 166. However, the percentage of the total fiber production has remained the same. The consumption of wool as shown by the figure on page 167 has shown a slight increase in the last few years.

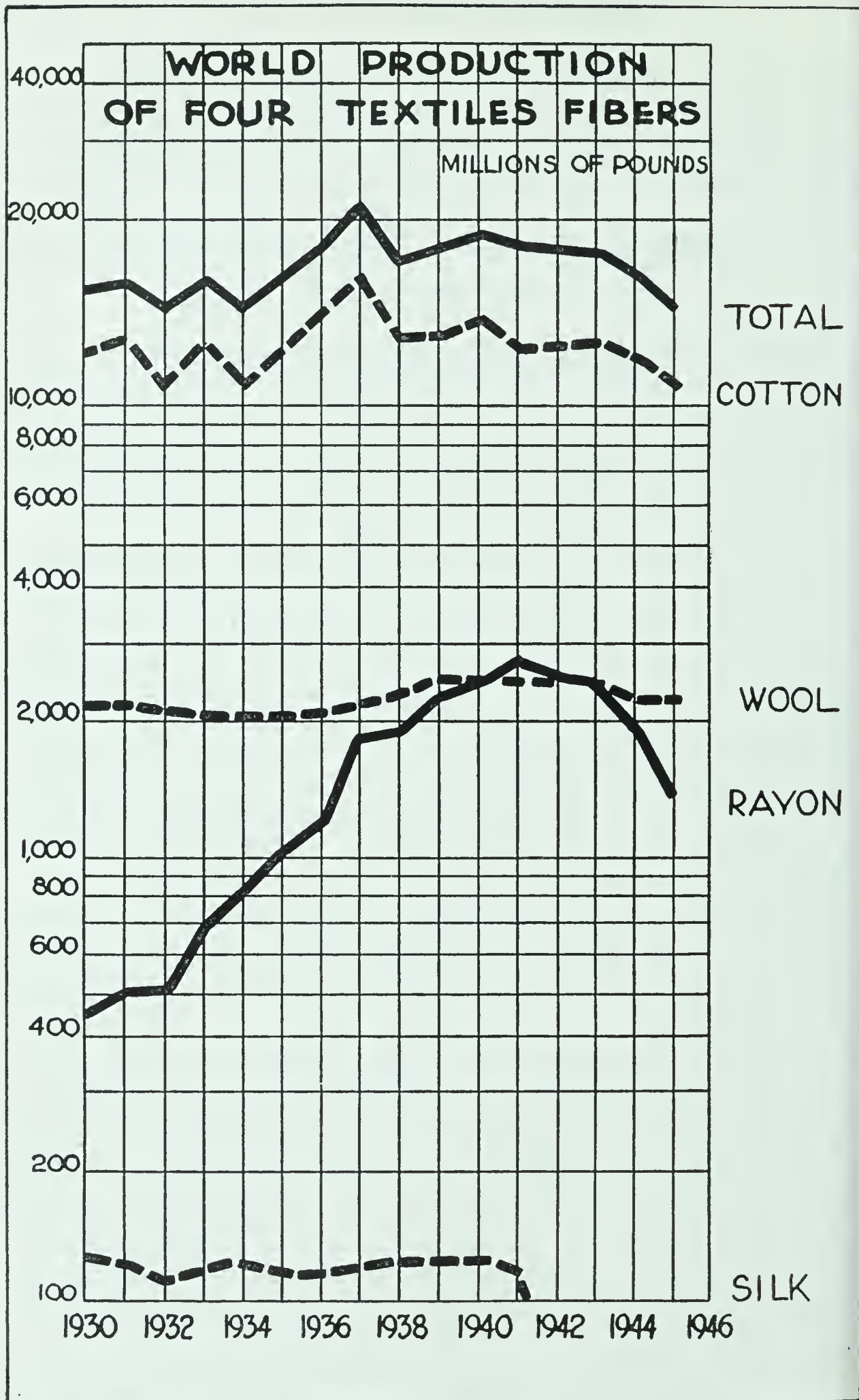
PROBLEM 1. WHY IS WOOL THE MOST VERSATILE FIBER?

An ideal fiber for use in the construction of clothing would be attractive in appearance, pleasing to the touch, dye easily and permanently, be plastic enough to be formed into any shape, and resilient enough to retain that shape. It would never wear out, afford protection from heat and cold alike, not absorb odors, and be easily cleaned.

Structure. Let us study the properties of wool and see how nearly it meets the requirements of an ideal fiber. An examination of the fiber itself will aid us in understanding its properties and the uses for which it is peculiarly suited. Wool grows in small locks of several hundreds of fibers tightly bound together, averaging as many as 40,000 or 50,000 fibers to the square inch on fine-wool sheep. The individual fiber is an organized structure consisting of distinct layers of cells. These layers include the epidermis, the cortical layer, and in some cases the medulla.

The outer layer or *epidermis* consists of flattened, scalelike cells of varying shapes and sizes, each more or less characteristic of the different breeds of sheep. The scales may be continuous (one scale entirely encircling the fiber), overlapping at the edges; or they may overlap as the shingles of a roof, two or more making up the circumference of the fiber. In the fine fibers the edges of the scales fit more closely than do those of coarse wool. These scales are not visible to the naked eye but are easily distinguished even under low magnification and are the simplest means of identifying wool. The scales are of hornlike tissue and furnish the fiber some resistance to crushing strain. The scales are also responsible to a great extent for the durability of wool.

The characteristic felting quality of wool from the various animal sources is possessed by no other natural fiber. For



World production of cotton, wool, rayon, and silk in pounds.

many years the felting of wool has been considered to be due entirely to the possession of the covering of scales which become gelatinous or glue-like when subjected to heat, pressure, and moisture. It is maintained that the scales swell and tend to interlock into a compact mass which retains its shape when dried.

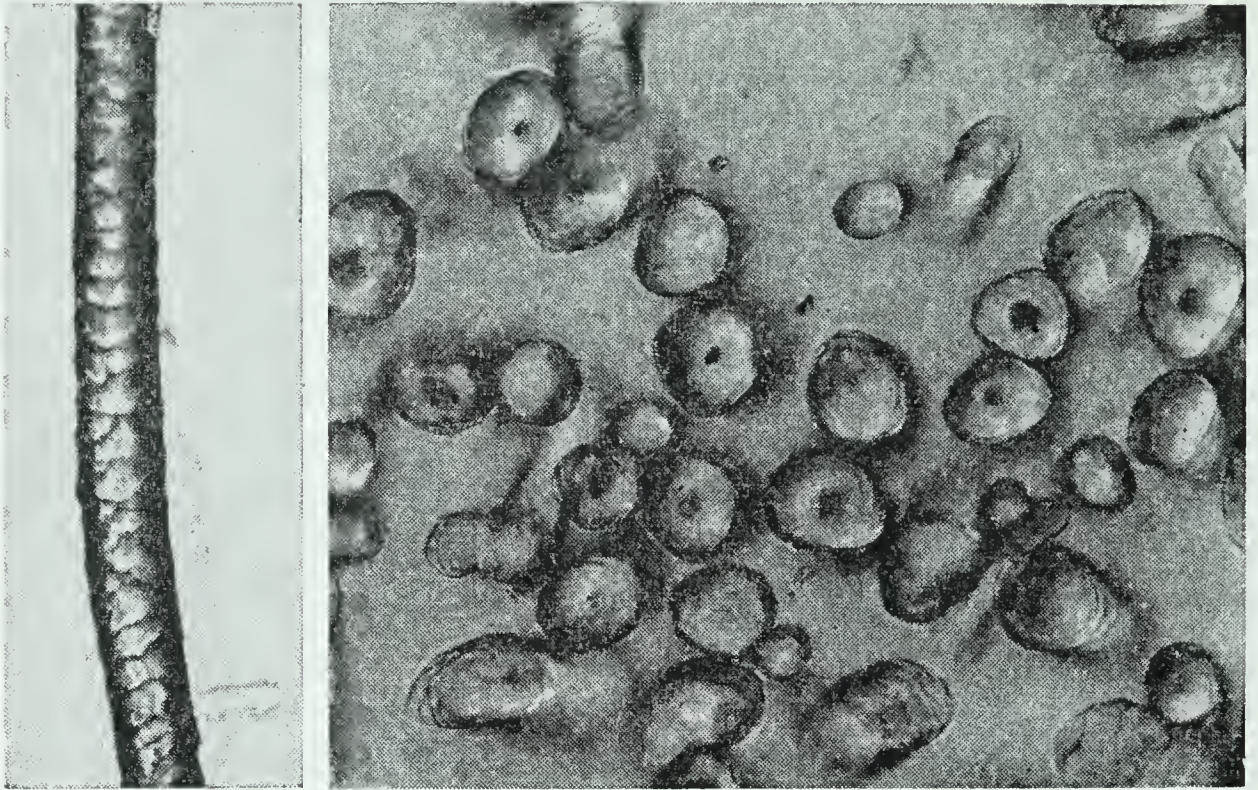
The fiber travel theory, based on the fact that the wool fiber moves only in the direction of the root end, is accepted by most authorities as the cause, or at least the principal cause, of felting. According to this theory, the application of friction in the felting process causes the loose ends of fibers to travel only toward the root end and thus become matted together.

The chemist adds to these theories. According to him, the felting property of wool is dependent upon its molecular structure. The protein molecule of wool possesses cross linkages which seem to be altered during felting. Processes recently developed reduce or entirely destroy the felting property of wool without injuring the scales or decreasing the strength or elasticity of the fiber. Thus a guaranteed nonfelting finish can be given to wool fabrics without decreasing their wearing qualities.

The wool fiber owes many of its individual characteristics to its structure which is really three-dimensional in nature. The cross linkages which exist between the lengthwise molecular chains hold the lengthwise chains apart and in case of distortion bring them back to position again. A wool fiber can be extended until it is double its length and it will return to its original length.

The luster of the wool fiber depends largely upon the size and nature of the scales as a reflecting surface. Scales that encircle the fiber, as in the merino, tend to break up the light less than scales that overlap as shingles on a roof. For the same reason coarse wools are often more lustrous than fine wools.

The second or *cortical layer* lies directly under the scales and makes up the body of the wool fiber. This consists of a layer of elongated cells of a fibrous nature, which give strength and elasticity to the fibers. The irregular growth of these cells produces the natural waviness of the fiber, which is an impor-



Longitudinal and cross section of wool fiber.

tant factor in the spinning of fine yarns, and may be an aid in felting. It is a generally known fact that coarse wool possesses less crimp than fine wool. The waviness of wool no doubt influences its elasticity, which is equal to or greater than that of any other fiber. Wool is high in resilience—that is, in the ability to spring back when compressed or folded. The great elasticity of the wool fiber and its resilience permit wool garments that have been stretched to regain their shape when folded or hung for a length of time. The ability of wool fabrics to hold and regain their shape makes them the material most suitable for men's outerwear. When wool has lost its so-called "life," it has lost its elasticity, resilience, and felting qualities. Garments made from this kind of wool will not hold their shape.

The third or *inner layer* of cells in the wool fiber is known as the *medulla*. This is not usually present in fine wool fibers but, under high magnification, can be seen in some coarse wools. This inner channel contains air spaces together with more or less connected groups of cells. The pigment or coloring matter of the wool fiber is contained in the form of granules in the medulla and also in the cortical layer.

In the pulling of objects past each other, the rougher the surfaces coming into contact, the greater the force that will be required to overcome the friction produced. The yarn manufactured from wool fibers combines this surface friction with tensile strength, and twist increases the resistance that these combined filaments offer to being pulled apart. This gives added strength to the tightly twisted yarns found in worsted fabrics. The felting of woolen goods adds strength by the interlocking and matting together of the individual fibers. For these reasons wool fabrics are among our strongest clothing materials.

Physical properties. The average length of wool fibers is between one and eight inches, and the diameter (according to Edward R. Schwarz) varies from 0.0018 to 0.0003 inches. There is some brown or black wool, but by far the greater portion is a light cream color. The breaking strength of wool varies greatly, one source giving a range of from 2.5 to 38 grams per single fiber. Its elasticity is the greatest of all the common textile fibers. Wool scorches easily and is injured somewhat by exposure to sunlight. Wool is attacked by mildew if left damp in a warm place.

All textile fibers are capable of absorbing moisture from the atmosphere; that is, they are hygroscopic. Wool is considered the most hygroscopic of all the fibers, being capable of holding as much or more than 30 per cent of its own weight in moisture without feeling wet to the touch. There seems to be little difference in the ability of the fibers to hold moisture in saturated air, but in atmosphere slightly less than saturated wool retains a much larger percentage of moisture than do the other fibers. The fact that wool gives up its moisture slowly may account for the relative comfort with which wool is worn even when wet. As the amount of moisture in a fabric increases its weight, wool piece-goods or garments for sale in bargain basements where the air is humid will tend to appear heavier than they really are.

The percentage of moisture in wool influences its breaking strength and elasticity as well as its weight, an increase in moisture content decreasing the breaking strength and in-

creasing the elasticity. For this reason it has been found necessary to establish a certain relative humidity and temperature at which all tests are made. The Bureau of Standards, Department of Commerce at Washington, D. C., and the American Society for Testing Materials, together with other testing laboratories, have accepted 65 per cent relative humidity at 70° F. as standard conditions for all textile testing. A tolerance of plus or minus 2 per cent is permitted in relative humidity and plus or minus 2° F. (1.1° C.) in temperature.¹ Tests should be made under these standard conditions, or reported in their terms for accurate comparison.

The variation in weight of wool due to the difference in the amount of moisture it contains has made it necessary to agree upon a definite per cent of allowable moisture or regain. Thirteen per cent of the oven-dry weight has been accepted as the percentage of moisture to allow for wool fabrics. Oven-dry and conditioned weight are obtained as follows:

The weight of wool dried at 110° C. until the weight remains constant is known as the oven-dry weight. The conditioned weight is obtained by adding to this weight the standard regain, or 13 per cent of the oven-dry weight. It is interesting, and sometimes necessary, to know the amount of moisture present in a fabric under natural conditions. The air-dry weight of the material minus the oven-dry weight gives the amount of moisture present. This divided by the weight of the air-dry specimen gives the percentage of moisture.

The air-dry weight minus the oven-dry weight (the amount of moisture) divided by the oven-dry weight gives the percentage regain—that is, the percentage of the oven-dry weight

$$100 \times \frac{\text{air-dry—oven-dry}}{\text{air-dry}} = \text{per cent moisture or moisture content}$$

$$100 \times \frac{\text{air-dry—oven-dry}}{\text{oven-dry}} = \text{regain}$$

$$\text{oven-dry} + (\text{standard regain} \times \text{oven-dry}) = \text{conditioned weight}$$

¹ *A.S.T.M. Standards on Textile Materials*, p. 74. Prepared by Committee D-13, American Society for Testing Materials, Philadelphia, 1944.

that the material has absorbed from the air. The oven-dry weight plus the (standard regain times the oven-dry weight) gives the conditioned weight.

Wool fabrics do not readily permit the flow of heat through them. There is little difference in the heat-retaining property of the individual textile fibers, but the nature of the wool fiber permits its being spun into a yarn containing many air spaces which, when this yarn is made into a fabric, prevent the flow of heat in direct proportion to the amount of enmeshed air. The nature of the wool fiber lends itself to the construction of a fabric with a napped surface, which does not become packed and hence retains its ability to hold air. The value of clothing as a protection from heat and cold, measured in terms of heat flow, is increased as the moisture content is decreased.

The density of the animal fibers—that is, the grams per cc.—is less than that of the vegetable fibers. The density of wool is 1.30.¹ For this reason wool fabrics are comparatively light in weight. The effect of temperature upon the weight, tensile strength, elasticity, and heat-retaining property of wool is much less than the effect of moisture on these properties.

Disadvantages of wool. Although wool is the most satisfactory fiber in many ways, it has certain disadvantages. Probably the greatest of these is the care with which it must be laundered to prevent shrinkage and hardening of the fabric. The same property that is an advantage in tailoring proves to be a disadvantage in laundering. Successful processing to produce a nonshrinkable fabric has overcome this disadvantage to a great extent.

Wool fabrics absorb and hold odors more than do other materials. Though these odors can be removed by laundering, this process may not be feasible, and dry cleaning it not always effective. A finish which overcomes this tendency of wool is known as Sanitizing. There is some evidence that bacteria are found in greater numbers on wool garments than on garments made from other textile fibers worn under the same

¹ Werner Von Bergen and Herbert R. Mauersberger, *The American Wool Handbook*, p. 120. The American Wool Handbook Co., 1938.

conditions. However, this need not be a health hazard, since dry cleaning kills approximately 98 per cent of the organisms that affect human health.

There is little difference between wool and other textile fibers in their ability to transmit ultraviolet light, and authorities do not agree as to the extent of this difference. However, the thickness of the fabric and the size of the interstices are the influencing factors in the transmission of ultraviolet light.

CHARACTERISTICS OF WOOL FIBERS

Microscopic appearance . .	Longitudinal—translucent with scaly surface Cross section—comparatively round with or without medulla
Length	2''–8''
Diameter	12–70 microns—great variation
Color	Cream
Luster	Low
Strength	4.5 to 38 grams per fiber
Elasticity	25–30%
Heat conductivity	Poor
Effect of heat	Scorches easily
Water absorbency	30% of weight
Standard regain	13%
Effect of moisture	Reduces strength and increases elasticity
Effect of sunlight	Comparatively slight
Attack by mildew	Yes
Attack by moths	Yes
Attack by carpet beetles . .	Yes
Effect of acids	Concentrated strong acids de- stroy; dilute acids, no effect
Effect of alkalies	Most sensitive

Suggestions for the Laboratory

Study under high power magnification mounted specimens of longitudinal and cross section of reprocessed and reused wool. Make drawings if time permits. Discuss the physical and chemical properties of wool as they affect the selection, care, and use of wool fabrics.

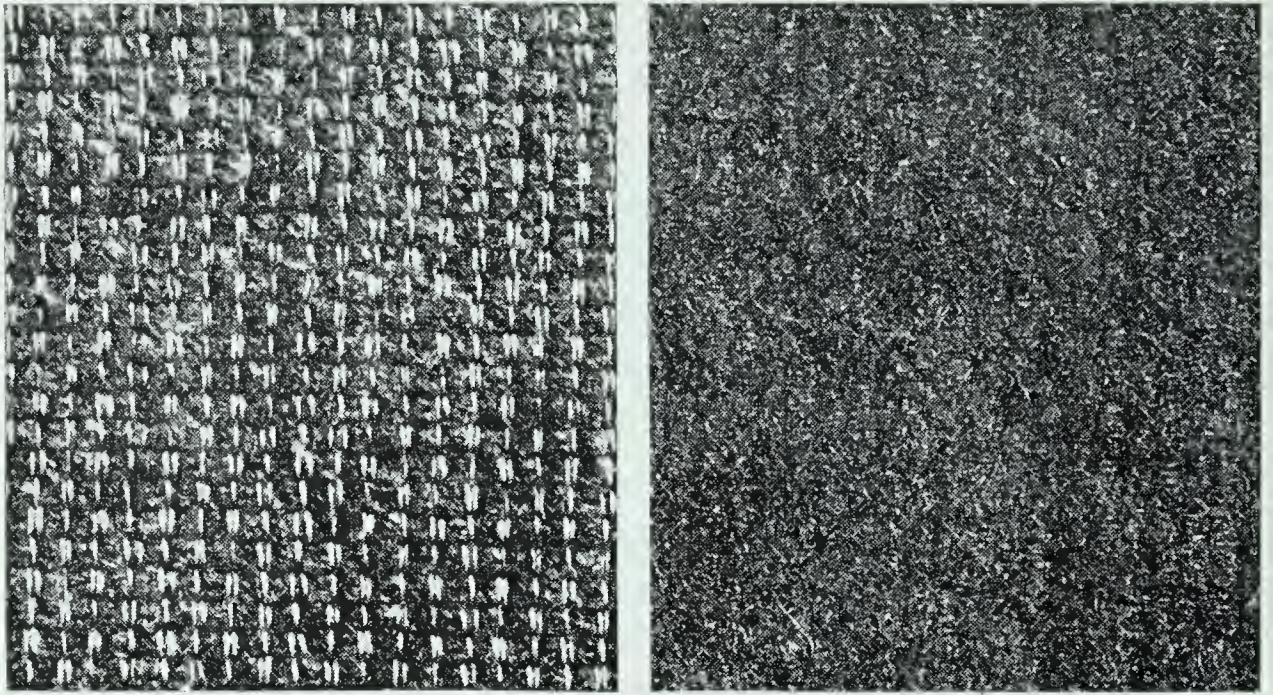
PROBLEM 2. WHAT IS THE COMPARATIVE VALUE OF "WOOL," REPROCESSED WOOL, AND REUSED WOOL?

The call of the rag man, "Wool rags, old bones, and bottles today?" has for many generations been heard on city streets. Have you ever wondered what was done with the wool rags, and what commercial value they really had? Worn-out wool garments have commercial value because they may be reduced to the fiber stage and manufactured a second time.

The Wool Products Labeling Act of 1939 became effective in July, 1941. In this act "wool" is defined as the fiber from the fleece of the sheep or lamb or hair of the Angora or Cashmere goat (and may include the so-called specialty fibers from the hair of the camel, alpaca, llama and vicuna). "Reprocessed wool" means fibers recovered from new rags never "utilized in any way by the ultimate consumer," and "reused wool" means fiber recovered from old rags "after having been used in any way by the ultimate consumer." "Carpets, rugs, mats, or upholsteries" are specifically exempt from the bill.¹ "The term 'virgin' or 'new' as descriptive of a wool product or any fiber or part thereof shall not be used when the product or part so described is not composed wholly of new or virgin wool which has never been used, or reclaimed, reworked, reprocessed or reused from any spun, woven, knitted, felted, or manufactured or used product." The act makes misbranding, under the provisions laid down, unlawful. Wool products, meaning anything or part thereof which contains or purports to contain reprocessed wool or reused wool must carry tags or labels. Percentages of wool, reprocessed wool, and reused wool, and any and all other fibers, each in excess of 5 per cent must be shown. Names of the manufacturer or of persons subject to the law must be given.

There is some question concerning any aid the consumer may receive from the passage of this act. No mention of quality is made and there is no doubt that new wool varies greatly. One cannot tell from any laboratory test to what processes the

¹ Rules and Regulations under the Wool Labeling Act of 1939, Federal Trade Commission.



Fabric woven from 85 per cent reworked wool, 15 per cent cotton with all cotton warp. Left, fabric as it comes from the loom; right, fabric after finishing.

fibers have been subjected. Microscopic and chemical examination will prove the quality of the fiber and the degree to which it has been broken down.

As there are no tests that can prove the accuracy or inaccuracy of the label, the act cannot be enforced and there is no doubt that in some instances the rules have not been followed.

One of the greatest difficulties arising from the use of the terms as given in this law is that there is no generic term left to cover the three types of fibers specified. In the following discussion, the term wool will be used in its common meaning, that of all fibers grown on sheep. When only new fibers are indicated, quotation marks will be used indicating the term as defined by the labeling law.

A large portion of the reprocessed and reused wool is utilized in the construction of cloth. The elimination of these two types of wool from the market would cause wool fabrics to be much higher priced. The physical properties, and therefore the wearing qualities of reprocessed and reused wool, are determined by the physical properties of the original wool, the processes by which it was first manufactured into cloth, the amount of wear it was given, and the process by which it



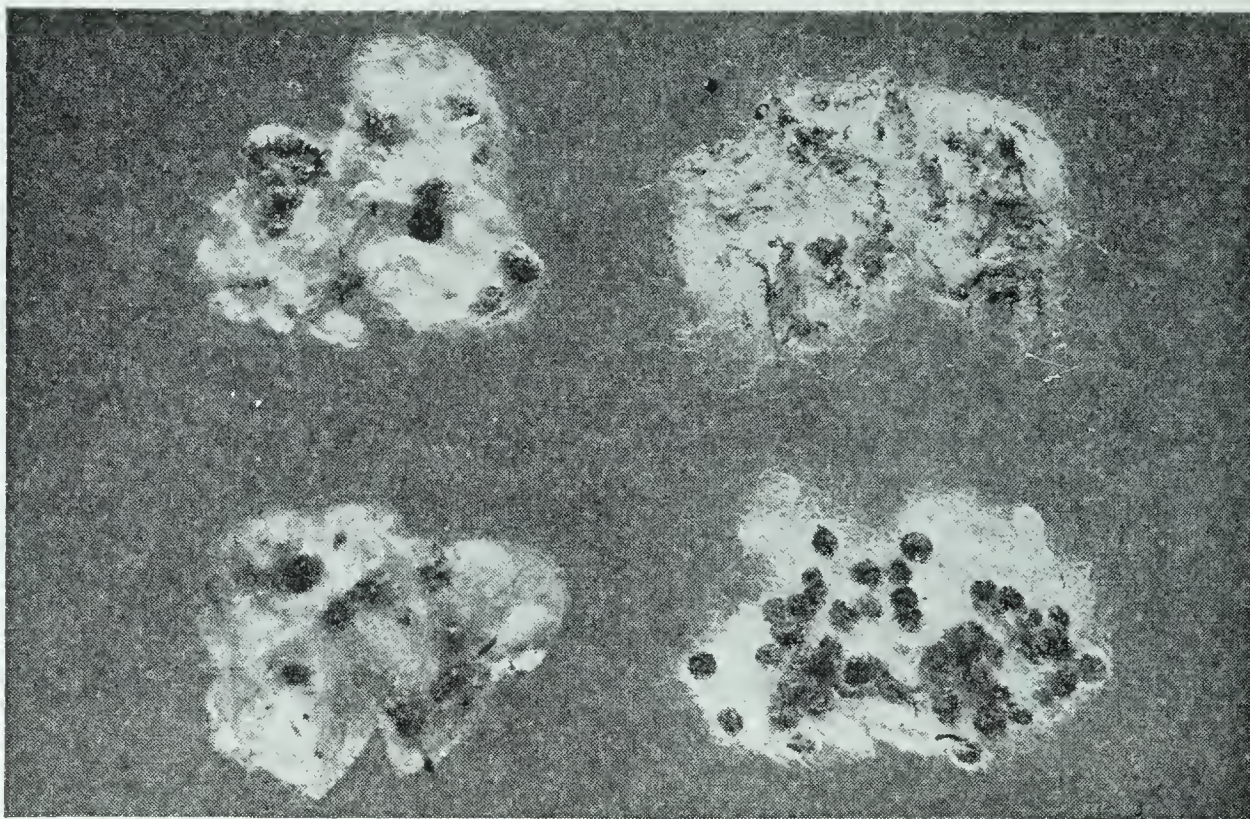
Courtesy U. S. Department of Agriculture

Wool-grading laboratory.

was reduced to the fiber stage. An evaluation of such fibers requires that we know something of the classifications and qualities of wool.

Wool fibers vary in quality not only with the different animals from which they are taken but also on various parts of the individual animal. Pure merino sheep produce fleece of more even quality throughout than any other type; the widest range of quality exists in the coarse wool of the mutton sheep. The wool from the shoulder of the animal is considered best for strength, quality, and length; that from the sides is next, the quality decreasing backwards over the body. The wool on the legs is generally torn and ragged. The fibers resulting from the first clipping or "lamb's" clip are short, fine fibers, and have one pointed end. These characteristics permit the production of a fine yarn but may reduce the commercial value of the clip. The nature of the pasture or range land, climatic conditions, health of the animal, and in the case of farm sheep the conditions under which they are stabled, determine to a great extent the character and amount of foreign matter that will be contained in the raw wool.

The cost of production of wool in any country is dependent



Courtesy James Chittick, permission E. F. Houghton and Co.

Samples of wool showing extreme burry condition.

upon many factors, among which suitable climate and abundant pasturage are important. Not less important are labor costs. The life of a shepherd on the range is a lonely one, and if other occupations are open to him, labor competition may necessitate paying a higher wage, thus increasing the cost of wool production.

WOOL CONSUMPTION IN MILLIONS OF POUNDS ¹

	APPAREL CLASS	CARPET CLASS	WOOL TOTAL
1940	312.2	98.5	411.1
1941	518.9	133.3	652.2
1942	570.0	43.8	613.8
1943	595.6	32.4	628.0
1944	578.0	42.9	623.9
1945	591.5	56.7	648.2

¹ *Rayon Organon*, February 1947, pp. 28, 29.

“Wool” is classified as *fleece* or sheared wool—that taken from the living animal—and as *pulled* wool—that removed



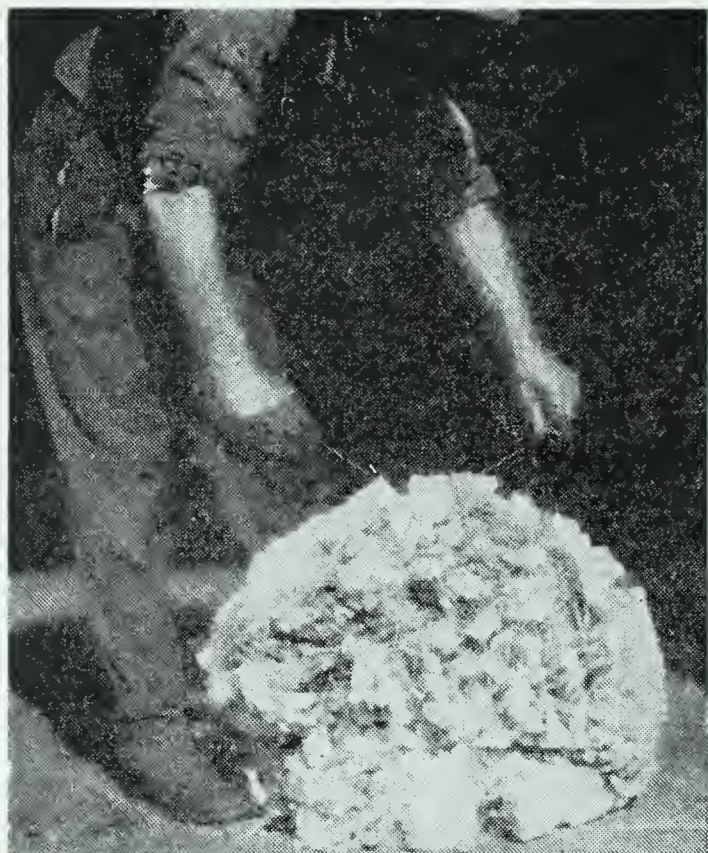
Courtesy Department of Animal Husbandry, Kansas State College

Machine shearing is rapid and has largely replaced hand shearing.

from the pelt of a slaughtered animal. Of these, sheared wool is by far the most important, as about 85 per cent of the annual domestic production of wool is of this class and only 15 per cent is of the pulled-wool class.¹ The production of wool in the United States in 1945 was the smallest since 1929.

The manner in which the sheep are sheared and the subsequent packing and handling of the fleece are influencing factors in the quality of the wool. Machine shearing has replaced hand shearing to a great extent in most parts of the world. (See page 193.) The time of shearing depends upon the climate, beginning in the South many months earlier than in the northern states. This permits the expert shearers to travel from one part of the country to another. Machine shearing is not more expensive on a large commercial scale but would prove prohibitive, as to cost, on small farm flocks. Hand shearing leaves ridges over the animal's body. The short wool of the face and other parts may be left uncut and many parts are

¹ Werner Von Bergen and Herbert R. Mauersberger, *The American Wool Handbook*, p. 217. The American Wool Handbook Co., 1938.



Courtesy Department of Animal Husbandry, Kansas State College

The manner in which a wool fleece is rolled and tied.

and many of them are packed into large bags or bales. Paper twine is used in the United States for tying the rolled fleece as fibers from jute and hemp twine are difficult to remove. The bags when filled weigh from 250 to 400 pounds. Care should be taken to pack separately wools of different types and values. Careless packing and storing are frequent causes of low grading of American wools, with consequent loss to the grower.

Pulled wool. Sheep may be clipped before shipment to the slaughter house, but this might cause the animal to be bruised and thus reduce the value of the mutton. For this reason many sheep, especially lambs, are not clipped before being slaughtered. All pulled wool will contain the root of the fiber; therefore it will have one closed end which may interfere with absorption of dyes. Although inferior to fleece wool of the same quality, pulled wool must be classed as new wool, if it has never been through the manufacturing processes. The amount of pulled wool on the market has increased with the development of the frozen mutton trade.

cut twice. The fibers of the entire fleece will probably be shorter than necessary and there will be many fibers which appear as waste during manufacturing processes. Care must be taken not to cut or injure the sheep, as this results not only in damage to the wool of the next fleece but also in possible loss of the animal.

The weight of the fleece from different animals varies greatly but will average about eight pounds. Each fleece is rolled tightly and tied,

Pulled wool lacks elasticity, life, and luster, in contrast to sheared wool. The condition of the skins and the method by which they are pulled both have a determining influence on the quality of the fiber. Pulled wool is classified according to the process by which it is removed from the skin. The three chief processes are sweating, lime, and depilatory.

In the sweating process the skins are hung on racks in a room where a high relative humidity and temperature are maintained. Bacterial action destroys the soft connective tissue and permits the fibers to be pulled from the skin. If the process is correctly carried out, both the fibers and the skin are marketable. If allowed to remain too long, the skins are injured.

The lime process has succeeded the sweating process, to a great extent. In this method lime $\text{Ca}(\text{OH})_2$ is painted onto the flesh side of the skin. The lime is allowed to remain overnight and is removed in the morning by washing. The loosened fibers are then pulled from the skin.

The depilatory process, which is faster and cheaper than the lime process, is used extensively in the United States. The skins are painted on the flesh side with a water solution of sodium sulfide and lime. Every pore leading to the roots of the hair must be covered with the solution without allowing any to come in contact with the wool side of the skin. The skins are then folded and hung on racks where they remain about twenty-four hours. Many pulleries maintain refrigerating plants where the skins are hung to prevent damage which might result from high temperatures. In this process the skins as well as the fibers are marketed.

A method of pulling wool by means of enzymes was developed in Germany. A solution of enzymes and certain chemical compounds is spread by hand or with a brush onto the flesh side of the skins. The skins must be cleaned somewhat by washing or rinsing and stored in a warm place before the solution is applied.

From 12 to 15 pairs of skins which have been piled with the flesh sides together are stored for about 24 hours. The temperature must be controlled to prevent injury to the

skins. After the wool has been scraped off, both wool and skins are rinsed in water. The skins are passed on for further processing and the wool is dried.

The lime and sulfide methods are cheaper and quicker than the enzyme method. However, the increased cost is more than made up in the increased value of the fiber in the latter method.

Pulled wools are graded according to their length, which is determined by the number of months that have elapsed since the sheep were sheared. Because the skins are scoured before pulling, there is less shrinkage in these wools than in fleece wool sold in the grease. They are considered inferior to fleece wools because the roots are damaged by the chemicals used. Pulled wool varies in price, depending upon the grade and the year, but is somewhat less than fleece wool of the same grade.

Pulled wools of short length are blended with other short-length wools and with cotton and rayon in the production of lower grades of woolen goods. Some blanket manufacturers use large quantities of the finer grades of pulled wool. The longer lengths are blended with fleece wool but seldom handled alone.

Both fleece and pulled wool may contain kemp, a straight, coarse, white fiber lacking strength and elasticity which, when found, is more or less mixed with the other fibers. These do not react to dyeing and finishing processes the same as the normal wool fibers and therefore show up as specks in the finished article. The presence of kemp in a fleece reduces its value.

Wool fibers are classified according to diameter as fine, medium, coarse, and carpet wool; according to length as long, medium, and short. They are further classified according to length as combing and clothing wool. Combing wool includes the fibers that are combed in the preparation of worsted yarns. Clothing wools are less than two inches in length and are used in the construction of woolen yarns. Combing and clothing wools of the same grade vary about ten cents per pound in price. The difference in price between the various grades in

either class is about seven cents. With such variations existing in wool the flat classification of all reprocessed or reused wool as of a lower quality is questioned. Insight into the matter may be gained by a study of the processes involved.

Reprocessed wool. In England a method for reworking textile materials into fibers originated over one hundred years ago. The first patent on rag-pulling machinery was taken out over one hundred years ago. The first reworked wool mill to be established in the United States was founded in Quebec, Vermont, in 1836 by Albert Getatin Dewey. The Dewey plant is being operated today by a member of the fourth generation of Deweys.

The term "shoddy" was used for wool fibers produced from knitted goods, "mungo" for those produced from woven material, and "extract" for those obtained from carbonized material. At present the word "shoddy" is rather commonly employed to indicate any material or fabric of inferior quality. This has resulted in a prejudice against remanufactured wool that seems unjustified. It has been suggested that a new term of two or three syllables for this type of wool would assist in destroying the wrong impression of inferiority that is attached to the term "shoddy."

Reused wool. High-quality fibers can be produced from discarded fabrics if they contain good quality unfelted fibers that have not been severely treated. A good quality of reused wool when woven into a fabric has greater resistance to abrasion than an inferior quality of wool fabric produced from fibers that are irregular and weak in spots or lack the protecting scales. Only a small portion of reused wool is used in the manufacture of worsted yarn, but the reused fiber industry has great economic importance in the manufacture of woollen fabrics.

The method by which the fibers are produced from the rags influences to a great extent the quality of the material. Great care and knowledge are necessary for properly sorting the fibers to make the most economical use of them. Fibers that have not been worn or injured in such a way as to destroy the

felting property will still possess strength and elasticity. Fibers that possess these qualities plus sufficient length to permit the spinning of satisfactory yarn allow the production of a fabric that will give good service. However, reused wool is used almost entirely in the production of low-grade woolen cloth.

The three main classes of reprocessed and reused wool fibers are shoddy, mungo, and extract. These qualities or classes are determined by the type of rags from which they are taken.

Shoddy includes fibers obtained from cloth that has been felted but slightly, such as worsteds and knitted goods. These fibers are one-half inch or more in length. Their quality permits the spinning of them alone in the manufacture of woolen yarn. However, shoddy fibers are usually mixed with short fleece wools in the production of woolen yarn.

Mungo refers to a class of fibers produced from fabrics that have been heavily fullered or felted. The severe treatment necessary to reduce this type of cloth to the fiber state injures the fibers, and the heavy felting given the original cloth tends to destroy the felting property. Fibers of this type are not used alone in the manufacture of cloth. They are usually found in cheap woolen blends.

Extract wool is produced from mixed goods, that is, wool blended with cotton, rayon, or other vegetable fibers. In the process of reclaiming the wool fibers from mixed goods the vegetable matter is destroyed chemically by a method known as carbonization. This process, if properly carried out, does not injure the wool. Fleece wool may be subjected to such a process before it is carded or spun in order to remove burrs and other vegetable impurities clinging to the fibers.

Rags are carbonized by treating them with an acid material such as sulfuric acid, hydrogen chloride gas, aluminum chloride or magnesium chloride, which reacts with the cellulose and forms an easily pulverized compound. The dried carbonized rags are subjected to a mechanical process called dusting which shakes out the charred cellulose.

A moderately high temperature is necessary with any of the

carbonizing agents. When sulfuric acid is used rags are steeped in hot dilute or more concentrated solutions. Acid hydrolyzes the vegetable matter to amorphous hydro-cellulose which is removed by dusting. Wool combines with a certain percentage of the acid which is later neutralized with a soda solution, the exact amount to be added being determined experimentally.

Since a hot aqueous solution of hydrogen chloride is injurious to wool, the hydrogen chloride gas is used for carbonizing. Heat causes aluminum and magnesium chlorides to dissociate to a minor degree, thus liberating hydrogen chloride, which acts as a carbonizing agent. When the aluminum salt is used the material is heated in the solution until the reaction takes place. If magnesium chloride is employed, the fabric is saturated with a solution of the salt, dried, and then heated until carbonization is complete. A rather high temperature is necessary to bring about the dissociation of the magnesium salt. The fabric is treated with the gas at a high temperature in a specially constructed apparatus. After two hours, cold air is introduced into the chamber and the gas is removed by a fan.

The sulfuric acid process is cheapest, is carried out at the lowest temperature, preserves the wool in good condition, but destroys the color. Hydrogen chloride is often used because it does not injure colors, but the corrosive gas requires special apparatus. In spite of the high cost of the reagent, aluminum chloride is often used for carbonizing. Neither the aluminum nor magnesium chlorides have an injurious effect upon colors. They do, however, require high temperatures which may injure the fiber, and a deposit of metallic oxide which adheres to the fiber must be removed.

Fibers reclaimed from by-products or waste from manufacturing processes are new fibers in comparison to those which have been sold, worn, and reduced to the fiber stage; however, they too have gone through some of the manufacturing processes. Probably the best type of these fibers is the "noils" which have been removed in the combing of the long fibers. These may be of good quality but too short to use alone in

the manufacture of worsted yarns. Waste from carding and spinning, from warping and weaving, and "flocks," the waste from scouring, fulling, and shearing, all find a place in the manufacture of wool goods.

The waste resulting from the tearing and grinding of rags, known as rag flocks, is generally used as stuffing material. The better-quality, longer flocks may be blended with other fibers and spun into yarns to be made into low-grade woolen goods. A large percentage of flocks is used as filling for materials, being fullled into the fabric during the finishing processes. The poorest grade of flocks is utilized in making embossed wall-paper.

How may the quality of wool fibers be determined? Some experienced persons may be able to recognize good quality fibers by the feel or hand of the cloth, but this method, although usually the only one available when purchasing fabrics, is not to be relied upon by most of us. For high quality yarns fleece wool is carefully selected for evenness of length and diameter and good quality of fiber. In good quality fleece fibers the scales will be distinct, not flattened or missing in spots, and the ends will be clean cut. Lamb's clip is not preferred for high quality yarns.

The comparative length of the fibers can be determined by untwisting a yarn and sorting the fibers. A microscope will be required for further examination. Even low power magnification will show the presence of lamb's clip which is recognized by one pointed end, and pulled wool which will be identified by a root end.

Research has proved that fabrics made from new high quality wool are somewhat superior to fabrics made from these same fibers after they have been reprocessed. It has also proved that much reprocessed and even reused wool is superior to some "wool." As most reprocessed and all reused wools have been taken from fabrics and reduced to the fiber stage again, yarns made from them usually contain fibers of varying sizes and many colors. The presence of fibers of this type would indicate reprocessed or reused wool. Torn and

split ends and flattened scales indicate poor quality fibers regardless of the class to which they belong.

Suggestions for the Laboratory

Study standard woolen and worsted fabrics and discuss articles for which they would be suitable. What is the present trend in the construction and finish of fabrics made from wool? Compare fabrics constructed of 100 per cent wool and blends with various fibers. What differences can be detected in these materials?

PROBLEM 3. HOW DO THE CHEMICAL REACTIONS OF WOOL INFLUENCE ITS USE?

Changes of temperature have a marked effect upon wool.¹ When heated to 212° to 220° F., the hygroscopic moisture normally held by wool is driven off and the resultant moisture-free wool is rough, harsh, and brittle, and lacks the original tensile strength. Moisture may be reabsorbed, but the softness, tensile strength, and elasticity are never entirely restored. Dry wool held at a high temperature for a period of time becomes discolored and gradually decomposes. Above 266° F. the protein breaks down rapidly, forming ammonia. As the temperature rises gases containing sulfur are given off.

The products obtained from dry distillation of wool are typical of the proteins; the complex molecule yields ammonia, hydrogen sulfide, water, gaseous hydrocarbons, carbon monoxide and dioxide, and free carbon. In the air wool burns slowly, forming a porous, brittle mass of carbon; the gases evolved have a disagreeable odor similar to that of burning feathers. Wool heated in moist air to 212° F. becomes plastic and is easily molded into shapes which are retained after the mass has cooled. This is of advantage in different finishing processes.

Moisture. Under usual conditions wool is insoluble in cold and hot water; however, continued boiling causes some de-

¹ J. Merritt Matthews, and H. R. Mauersberger, *Textile Fibers*, p. 575. John Wiley & Sons, New York, 1947.

composition of the fiber. Wool soaked in either cold or boiling water becomes softened and loses its strength, which is

THE EFFECT OF MOISTURE ON WOOL ¹

UNTREATED SAMPLE	BREAKING STRENGTH
Soaked in water one hour	145.0 pounds (original strength)
a. Tested wet	104.3
b. Air-dried three days	140.8
Boiled in water one hour:	
a. Tested wet	83.6
b. Air-dried three days	128.3

partially restored by drying. The table given above illustrates the effect of moisture on wool.

Wool which has been heated under pressure in water to 268° F., then dried, is easily pulverized. Since pressure and water are employed in such manufacturing processes as scouring, mordanting, and dyeing, it is evident that prolonged treatment in any of these processes would cause a loss of strength and elasticity.

Steam is important in the finishing of woolens and worsteds. Wool which has been steamed at a high temperature manifests an increased affinity for dyestuffs. Piece goods are often preshrunk by placing them on blowing machines until thoroughly saturated with steam. This method of shrinking is quick and cheap but may not give complete shrinkage and often causes the colors to bleed.

Acids. Dilute solutions of mineral acids, either cold or boiling, have no harmful effect on the wool fiber. The application of acid colors in a hot acid solution is therefore possible.

Wool tends to absorb both organic and mineral acids and to hold them even after thorough rinsing with water. An unstable chemical combination probably takes place between the protein and the acid. Wool which is treated with acid, especially sulfuric, has an increased affinity for acid dyes and less affinity for basic dyes. Tannin, fixed on the wool by a me-

¹ Reprinted by permission from *Textile Fabrics* by George H. Johnson, p. 49. Published by Harper and Bros., 1927.

tallic salt, increases the affinity for basic dyes and thus serves as an important mordant.

Wool treated with nitric acid assumes a bright yellow color which is due to the formation of xanthoproteic acid. The color is intensified by contact with ammonium hydroxide. This reaction is typical of a protein and may be used to determine the presence of protein fibers.

Wool dissolves slowly in cold concentrated solutions of mineral acids. Crepe effects are obtained by a brief application of concentrated acid under controlled conditions. Hot concentrated mineral acids completely disintegrate the fiber.

Alkalies. Wool is sensitive to alkalies. In the manufacture of any textile material, it is practically impossible to prevent it coming into contact with alkaline liquors. Dilute solutions of alkalies, if in contact with the fiber for only a short time, do not seem to injure wool, but they must not be dried on it. When boiled in a dilute alkaline solution for a few minutes, the fiber is completely destroyed. It is obvious that soaps containing free alkali, alkaline builders, and scouring agents tender wool. Ammonia, a weak base, if used in concentrated solution at a high temperature, causes disintegration which is shown in the early stages by a tendering of the fiber. Alkalies most safely used with wool are ammonium carbonate and borax.

Wool that is treated with a cold concentrated solution of an alkali for a short time under controlled conditions acquires a high luster and silky scroop and shows increased tensile strength. The increased luster and strength are probably due to the fact that the scaly covering fuses into a more compact and regular surface.

Bleaching agents. The natural color of the wool fiber is removed by reduction or oxidation. For this purpose a "sulfur" bleach may be used. The material to be decolorized is treated with sulfur dioxide gas, with a solution of the gas in water, or with a solution of sodium disulfite (NaHSO_3). Sulfurous acid, the active bleaching agent in each case, is oxidized to sulfuric acid, and the colored organic pigment is reduced to a colorless compound. By the reduction process it is impos-

sible to obtain wool that will remain white, as the colorless compound thus formed is gradually reoxidized by oxygen of the air to the original colored pigment. The yellowish cast is neutralized by tinting with a small amount of violet coloring matter. Wool bleached by the sulfur process cannot be used for the light colors without first removing all excess sulfurous acid with an oxidizing agent. A small amount of acid retained in the material would reduce the dye to a colorless compound.

Hydrogen peroxide is used extensively in the bleaching of wool. Other oxidizing agents, such as sodium peroxide and potassium permanganate, are finding increasing use in wool bleaching; although the reagents are expensive, conditions must be carefully controlled to prevent injury to the fibers, and the stock must be thoroughly cleaned before immersing it in the bleach. Impurities in poorly scoured wool react with the peroxide and soon destroy the bleach liquor. Bleaches brought about by oxidation are permanent and white. They are used for wool which is to remain white or to be tinted delicate shades.

Nonshrinkable wool. Much research has been directed toward the production of wool fabrics that will not shrink when laundered. This laundering shrinkage includes the contraction resulting from the releasing of strains set up in manufacturing and finishing processes and the felting which occurs in wool fabrics when they are worked under water. It is absolutely necessary that wool fibers possess this felting or milling property in order that finishing processes necessary to improve the appearance and texture of the cloth be carried on. However, this property is most undesirable in the finished fabric. Now, the consumer is demanding a wool fabric so treated that it can be laundered successfully.

Less than one per cent shrinkage in either warp or filling after 15 or 20 washings has been obtained for cottons and rayons, but this goal is seldom reached with wool fabrics. Thorough dry cleaning of wool often requires some moisture in the cleaning fluid to remove perspiration salts and water soluble stains, or the garment may be given a light wash in

water. Hence, nonfelting wool fabrics are recommended for use in garments to be dry-cleaned.

Nonfelting wool. According to Mauersberger, "elasticity and frictional effect of scale surface are responsible for the felting shrinkage of the wool fiber. Therefore, either the elasticity of the wool fiber or the directional frictional effect of its surface must be destroyed to prevent its felting. Since the elasticity of the fiber is the most valuable property, all methods of reducing the felting properties of wool aim at destroying or altering the frictional properties of the fiber surface. It is known that any chemical reagent which attacks and rounds off the free edges of the epidermis scales diminishes the felting of woollen fabrics."¹ He further cites authority for stating that, "with the newest methods, the scale structure is preserved but the layer under the scales is converted into a degraded protein capable of swelling under the action of acids and alkalies. Because the scales rest on this insecure foundation they no longer exert a directional effect on the frictional properties."

Methods first in use to reduce the felting property of wool damaged the fibers, and it has been the general opinion that nonfelting wool had been weakened perceptibly. Chlorine or bromine compounds in many forms have been utilized for this purpose. It is claimed that by the use of the gaseous form of these compounds nonfelting wool can be produced that has a more silk-like luster and in which the breaking strength has been increased from 30 to 50 per cent.

Formaldehyde, alcoholic potash, and fecin and papain enzymes have been used at different times to prevent felting with more or less success in some countries. However, none of these have proved completely satisfactory in America. A recent method of producing nonfelting wool is by treating it with synthetic resins.

As the felting of wool results to a large extent from its extension and contraction when manipulated under water as in

¹ *Textile Fibers*, Merritt J. Matthews and H. R. Mauersberger, John Wiley & Sons, p. 597, 1947.

laundering, by controlling or preventing this action the felting or shrinkage is reduced or eliminated. This change in properties is accomplished by causing simple molecules (monomers) to form synthetic resins (polymers) inside the wool fibers. Water vapor and a vinyl or vinylidene compound in vapor form have been used in England for this purpose. Under this treatment the wool fibers swell and the vapors enter the fiber. By raising the temperature these simple molecules are polymerized into chain molecules. The reduction in shrinkage by this method is explained as follows: Polymers formed within the wool fibers fill the space normally available for water vapor. This treatment reduces the elasticity of the fibers, thus reducing fiber movement within a fabric and the scales are more or less masked, reducing felting from this cause.

At the Stamford laboratories of the American Cyanamid Company, a resin was found that imparts good shrinkage control to wools. This resin is a condensate based on melamine, and is usually a methylal melamine or an alkylated methylol melamine. This material when applied is not, strictly speaking, a resin but a monomer capable of forming a resin under proper conditions. This treatment does not affect adversely any of the desirable qualities of wool, and its dyeing properties are often improved. It is predicted that the use of resins in the treatment of wool may result in a modification of the properties of wool in any desired manner.

PROBLEM 4. HOW DO THE MATERIALS AND PROCESSES USED IN THE MANUFACTURE OF WOOLEN AND WORSTED YARN DIFFER?

The fact that wide variations exist in the quality of wool fibers makes necessary a selection of fibers in order to have a high-class finished product. To produce a fine piece of wool fabric, only those fibers best suited to the processes through which they must pass can be used. Wool in the form of a tightly rolled fleece must be opened and separated according to the diameter, length, and quality of the fibers.

The sorting of wool, which is the first mill process, is really a division of the various portions of the fleece according to quality. This is done over a table that generally has a slatted or wire-meshed top which permits the coarse dirt to fall through. All sorting tables are located where there is good light.

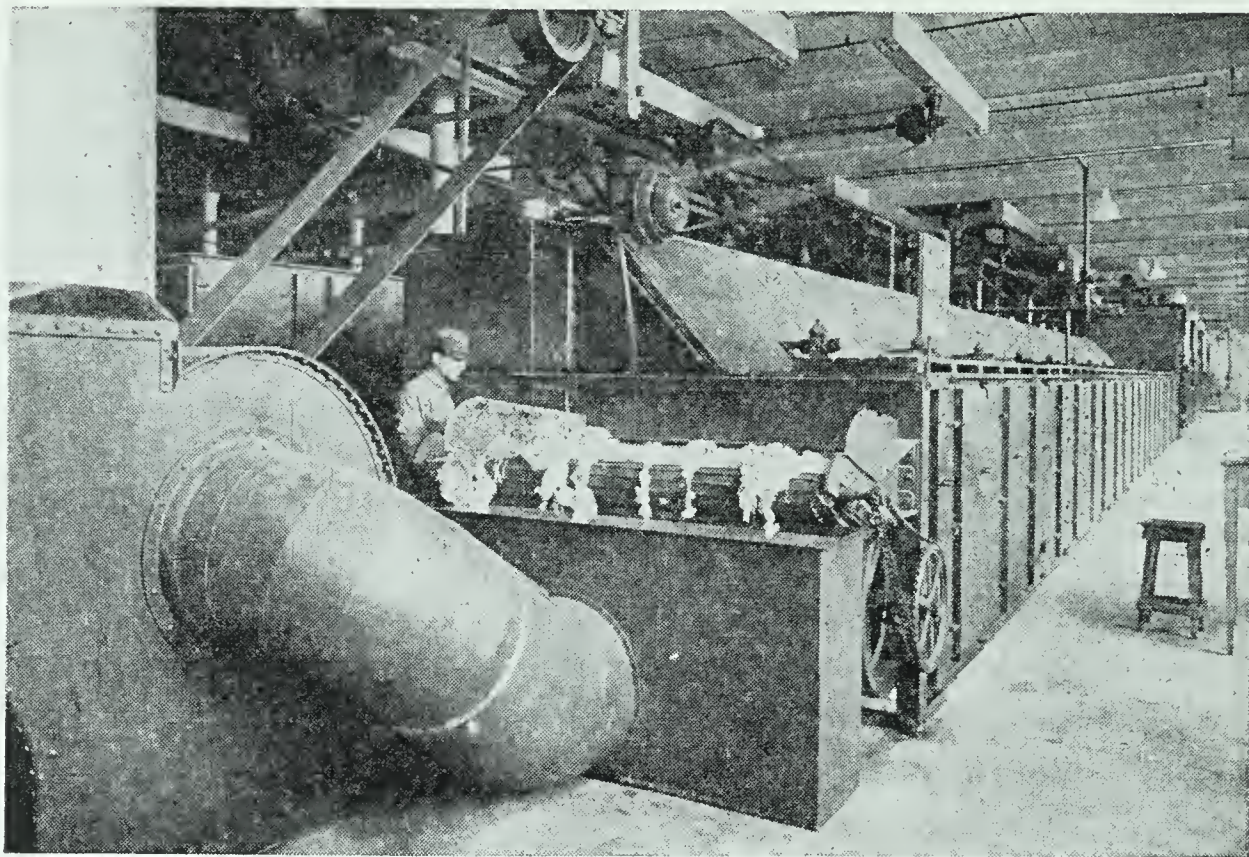
If the wool has been stored for some time it may be necessary to soften the grease by heat before the fibers can be pulled apart. The sorter opens up the wool, quickly removes the dirtiest parts, any wool containing tar or paint, and the largest burrs. With expert knowledge he separates the different qualities of wool, placing each in its correct pile. Fine wools of even quality require little sorting, but coarser wools may vary greatly in length and fineness throughout the fleece. Experience has taught the sorter the feel and general appearance of certain classes of wool so that he is able to detect the weak and defective fibers. Improvements in the machinery handling the wool have decreased the necessity of close sorting.

After the wool has been sorted, the next process is cleaning, because the fibers are too dirty to be processed. (See page 208.)

The substances in raw wool other than the fiber itself are of two types: natural and foreign. The fiber is developed from a root located in the second layer of the skin, each fiber being surrounded by sebaceous glands which secrete wool grease, and sweat glands which secrete the sweat; these two, sweat and grease, together are known as yolk.

The wool grease serves as a protection to the fiber, preventing the matting or felting of the fibers in the fleece. A lack of grease in the fleece may be due to heavy rains, poor housing, or a diseased condition of the animal. Sometimes the latter results in what is known as a cotted fleece, which brings a low price on the market.

The amount of pure wool fiber in a fleece varies from one-fourth to three-fourths of the weight of the raw wool. Fine wool will contain a larger percentage of wool grease due to the greater number of fibers per square inch, each surrounded by the sebaceous glands which secrete the grease.



Courtesy American Woolen Co.

Scouring and drying of wool.

Most animal fats such as lard and tallow are esters of the trihydroxyl alcohol, glycerol. In these fats, or esters, one glyceride group is found combined with three acid radicals of an organic acid such as palmitic, oleic, or butyric. These animal fats are insoluble in water and do not form good emulsions. They are easily hydrolyzed by boiling with dilute acids or alkalis such as caustic soda or potash, or by heating with steam. The hydrolysis of a fat when boiled with an alkali produces glycerol and the salts of fatty acids or soap. This process of hydrolysis of a fat by an alkali is known as saponification.

Wool grease or wool fat. Wool fat differs markedly in its chemical properties from most animal fats. Wool grease melts at between 95° and 100° F. Part of this grease is present as a free fatty acid which, combined with an alkali such as soda ash, forms a soap which aids in the scouring. A larger part of the grease is saponifiable only with caustic alkali at a temperature of nearly 212° F.

Chemically, wool fat is not a simple compound. Choles-

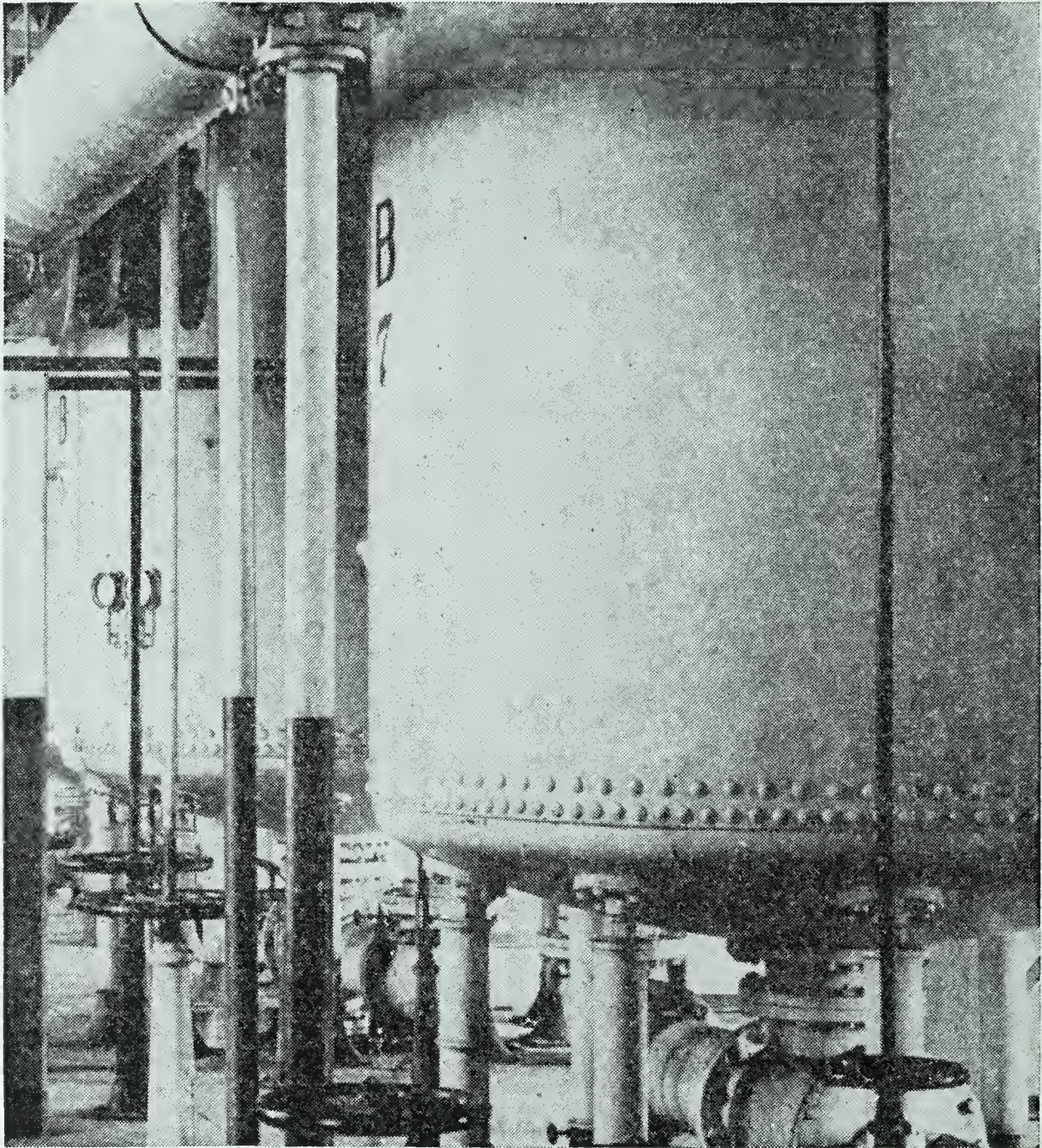
terol, its chief constituent, is a monatomic alcohol containing 26 carbon atoms in its molecule. Cholesterol occurs in tissues of the blood, brain, and the nervous system. This compound is not saponifiable, but with warm water and a slightly alkaline solution it forms a permanent emulsion. At present it is prepared on a large scale from wool fat and is utilized to some extent for softening leather and for belt dressings; but the most important use is in the manufacture of pharmaceutical salves. The latter, generally known as lanolin compounds, are valuable because the wool grease is readily absorbed by the skin. If suitable medicinal properties are incorporated with the grease, they too will be absorbed into the system. The healing qualities of wool grease and the pharmaceutical preparations made from it have been known and used since the time of the early Greeks.

The second natural impurity found in the fleece is dried sweat. This consists chiefly of potash salts and is sometimes used as a source of these substances. During the growth of the animal these potash salts prevent the deterioration known as *weathering*, which is due to the action of sunlight. The short light waves are said to cause the formation of an acid from the sulfur in the wool. The potash salts of the sweat tend to neutralize this acid and prevent weathering. Weathered wool is weak and brittle and takes dye irregularly. The sweat is soluble in water and easily removed from the fibers.

The foreign substances present in raw wool consist chiefly of *dirt* and *vegetable* matter. Much of the dirt is removed during the sorting and cleaning; the vegetable matter may be of such a nature that it must be chemically removed by means of carbonization, a process that has already been discussed.

Wool may be cleaned by *scouring* in soap and water, by use of a *solvent*, or by the *Frosted* method.

Scouring is the method generally used to clean the wool fibers. This method employs soap and an alkali in large wooden or metallic troughs or bowls; the fiber is slowly moved forward and immersed in the scouring liquor by means of rakes. Usually there are three bowls with soap and alkali, and a fourth is used to rinse the stock. After scouring, it is necessary



Courtesy Arlington Mills

Naphthalating plant.

to add a certain amount of easily saponified or emulsified oil to the wool. This is done to lubricate the fibers so they will slide past each other more easily, to help reduce static, and to reduce breakage. Clean wool, when dry, has no odor.

The solvent method of freeing the wool from impurities requires the use of such liquids as benzene, petroleum naphtha, and carbon tetrachloride to dissolve the oils and fats. (See page 210.) The foreign material remaining is removed with

warm water. The severe action of soap and alkali on wool is avoided in this process. However, the dangers accompanying the handling of large quantities of highly inflammable solvent have deterred its general use.

The process known as *Frosted Wool* removes a large amount of the impurities from wool by means of freezing. At low temperatures the natural oil or grease becomes congealed and can be reduced to dust by mechanical means. The removal of the frozen grease permits the fibers to be separated and the vegetable matter to be removed. Branding paints and tar can also be removed from frosted wool by mechanical means. Frosted wool may need to be scoured to remove the last traces of grease, but it has been proved that wool that has been cleaned by the Frosted Wool process before scouring is not only entirely free from vegetable impurities but is of much better color than the same wool not so treated. By this method low-priced, burry wools may be quickly and economically converted into higher-priced fiber. Microscopic tests have shown that by this process the fibers are not injured in any way.

The difference between the weight of the clean wool and that of the raw wool is known as *shrinkage* and is an important factor in the grading of wool. In England, the term *yield* refers to the quantity of clean wool obtained from one fleece. The amount of shrinkage determines to a great extent the price per pound which the grower will be able to obtain for his clip. Wools in the United States are estimated to shrink between 50 and 60 per cent, on an average.

After cleaning by the scouring or solvent method it is necessary to remove the vegetable matter either by mechanical or chemical means. Otherwise, the burrs would continue to be broken finer and finer but would not be removed and would interfere with all of the later processes. The burr-picker is the apparatus used to mechanically remove the burrs. The modern type of machine employs four distinct operations each of which contributes its part to the removal of the vegetable matter.

Carbonizing, the chemical process used to remove the vege-

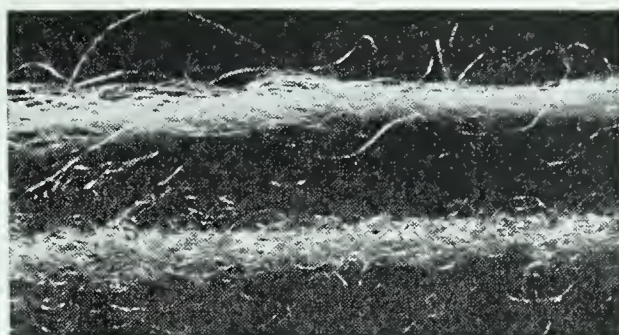
table matter, is far superior to burring. By this method every trace of vegetable matter can be removed. The vegetable matter is destroyed by acids such as sulfuric or hydrochloric or by salts of aluminum chloride which produces acid when heated to a high temperature. The vegetable matter is reduced to a carbon compound which is removed by dusting. If sulfuric acid is used the wool must be neutralized. Since aluminum chloride is a milder reagent, there is less danger of injury to the wool and neutralizing is unnecessary.

With the exception of the small percentage of wool fibers used in the manufacture of felt, it is necessary to convert the loose fibers into yarn before they can be made into fabrics. Yarn may be purchased by the consumer for use in hand construction and decoration, but most of it is manufactured into cloth.

Woven wool fabrics, which constitute the greater portion of wool goods, are divided into two distinct classes known as worsteds and woolens; the characteristics of each class are determined by the nature of the yarn used and the finish given the fabric. Worsted yarns are more or less tightly twisted, firm, and smooth, with fibers lying in a parallel manner, and with comparatively few protruding ends. Woolen yarns are usually softer and present a fuzzy appearance, due largely to the fact that the fibers are more or less tangled and criss-cross. (See the illustration at the top of page 213.) Factors which affect the quality of the finished product are to be found in every step of its manufacture from the grading and sorting of the fibers, when the longest and finest fibers are separated from short, coarse ones, through the remaining processes.

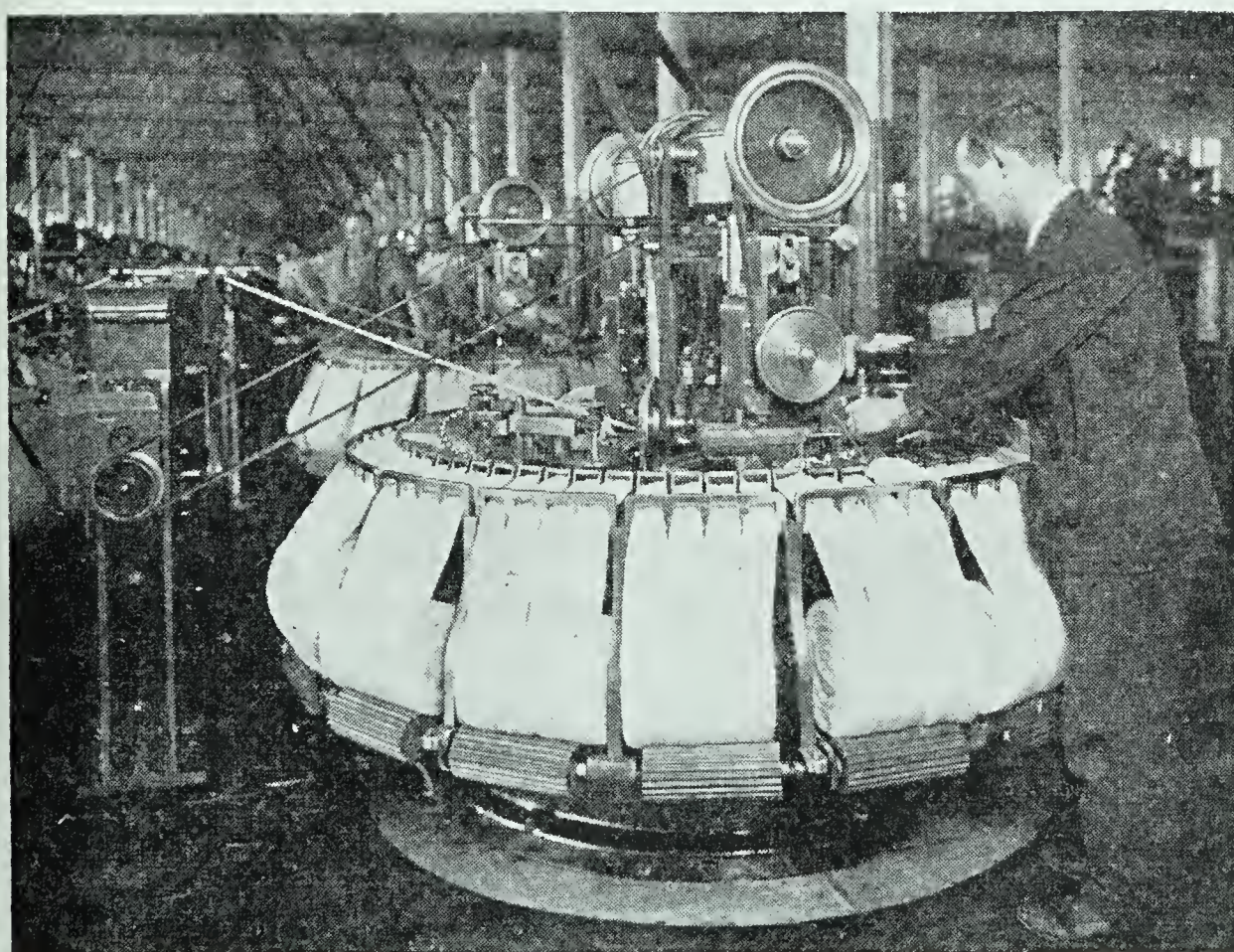
Worsted yarn. A worsted yarn is any yarn made from wool fibers in which the fibers are practically parallel with the length of the yarn, regardless of the length of the fibers. One objective of all worsted yarn manufacturing processes is to lay the fibers parallel to each other. Carding opens, cleans, and begins to parallelize them. A worsted card consists of several cylinders covered with fine wire teeth known as card clothing. This card delivers a soft sliver suitable for the following machines.

The Noble comb, which is adapted to handling long fibers, is in greatest use to-day on all grades of wool which have good length. (See below.) The French comb was developed so that short and mixed fibers could be combed and used in worsted yarns. This comb turns out a slightly superior product at a higher cost.



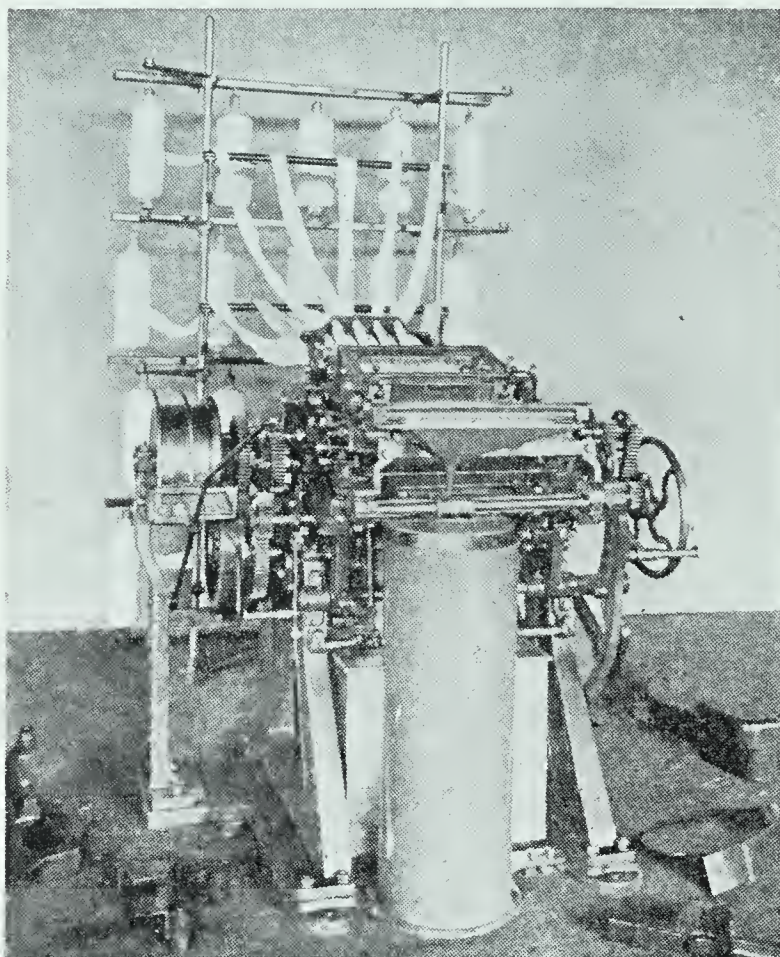
Worsted and woolen yarns. The long fibers, in the worsted yarn, are shown lying practically parallel to its length; the shorter fibers, in the woolen yarn, lie in every direction.

It is necessary to oil wool that is to be combed with the Noble comb, but the French comb handles "dry" stock. The Lister comb, which combines something of the principle of both the Noble and the French comb, is used especially for mohair. It is also used in the combing of reclaimed wools.



Courtesy American Woolen Co.

The Noble comb.



Courtesy Atkinson, Haserick and Co.

French comb which handles short and mixed fibers.

long, medium, and good-length fine wools. This inserts some twist in every step of the process and produces a smooth, compact roving. In this roving the fibers are laid in a curved form rather than parallel to its length. The cone drawing system uses the minimum amount of twist and with the same material produces several counts better spinning quality but requires a higher class of labor. In the French or porcupine system no twist is inserted at any point.

Woolen yarn. A woolen yarn is any yarn made from wool fibers in which there has been no attempt to lay the fibers parallel with the length of the yarn, regardless of the length of the fibers. The manufacture of woolen yarn is entirely different from the manufacture of worsted yarn.

The characteristics of woolen yarns and the type of apparatus used permit the combining of coarse short fibers with reprocessed and reused fibers in varying proportions. In ex-

The character of worsted yarn is largely determined by the drawing operations. Every type of wool fiber of suitable length can be converted into worsted yarn by one of the two systems of drawing commonly referred to as English and French. Both the open and cone systems are referred to as English. The porcupine system is known as French.

The open system of drawing is used in the handling of

treme cases, as high as 90 per cent of these fibers may be used.

The preparation of stock for woolen yarn includes the blending of the various types of materials. Fibers, whether new or reprocessed wool, wool and cotton, or wool and rayon, must be of similar length and fineness and possess the same spinning qualities in order to blend into a homogeneous yarn. Carding of fibers for woolen yarn differs from the carding of all other fibers except cotton waste. The fibers must be separated and cleaned but left lying in every direction. The mule is almost universally used in the spinning of woolen yarn, although woolen yarn of good quality can be produced on the continuous-ring spinning frame.

The unit of length in woolen yarn is designated as a run, which consists of 1600 yards. Thus a 1^s of woolen is a yarn 1600 yards of which weigh 1 pound.

PROBLEM 5. HOW DO THE TYPE OF YARN AND PROCESSES INFLUENCE THE CHARACTER AND PROPERTIES OF THE CLOTH?

A discussion has already been given of the individual characteristics imparted to fabrics by the various methods of construction and the type of yarns used. In all fabrics and especially in those made from wool, the method of construction may be almost obscured by the finishing and other processes.

Clear-finished fabrics. Worsted yarns, being made of fibers lying parallel with the length of the strand and tightly twisted, are especially suited to the construction of fabrics having a design or a twill weave. Worsted fabrics are usually given a clear, thready, or base finish which further brings out the luster of the fiber and the design of the fabric. Fabrics to be given a clear finish must be singed to remove the projecting ends of fibers, leaving the surface clear or bare. (See page 102 for further discussion.) As the fine worsted yarns are comparatively light in weight and small in size, a compact, lightweight, firm fabric may be constructed from them. These fabrics as a group are lighter in weight than the woolen

materials. The twisted yarn made of the finest, best quality of fibers produces cloth that will stand hard wear. The smooth surface of worsteds resists dust and is therefore comparatively easy to keep clean. They are appropriate clothing fabrics for business or school wear. The smooth surface of some of the hard-finished worsteds will tend to become shiny, which may be a disadvantage. Today rayon and other synthetic fibers are blended with wool in various proportions in the construction of many novelty and staple worsted fabrics.

Napped finishes. Woolen yarns, being made from fibers lying in every direction of the strand, produce a fabric of entirely different characteristics. Cloth constructed of these yarns is generally finished with a nap. This increases the soft, full feeling. (See page 106.) Blankets and heavy material made for warmth are often constructed of woolen yarns, felted and finished with a nap. This permits the material to enmesh large quantities of air which is the greatest factor in the ability of a fabric to retain heat. Woolen fabrics are seldom constructed with a figure weave but may be of a twill weave, as this furnishes the best surface for napping.

An examination of woolen fabrics on the market shows that other fibers are often blended with wool in their construction.

The size of the yarn and the number of picks and ends per inch will determine the weight per square yard and to a certain extent indicate the serviceability of a fabric. Material of such loose construction that the yarns push apart is not satisfactory for most uses. Wool fabrics of loose construction made of woolen yarn may be felted or fulled until they become compact. A heavy napped surface improves the appearance of inferior material. Short fibers may be picked into the surface or sifted onto it and felted to bind them there. Can you name several standard and novelty woolen fabrics?

Combination of yarns. Besides the woolen and worsted fabrics we have materials constructed of a combination of these yarns; the fine worsted yarn in some cases serves as the warp, and a larger, soft, woolen yarn as the filling. Some broadcloths and lightweight flannels use this combination of yarn. These materials are napped but are lighter in weight, and the back

is of different texture from that of fabrics in which the warp yarn is the same as the filling yarn. Novelty fabrics are produced by many different combinations of various types of yarns.

Knitted fabrics. Yarn, to be used in knitting, must be soft, elastic, round, and uniform in diameter in order to form the loops correctly. The knitting of such yarns results in soft, elastic fabrics, which may vary in weight, compactness, and finish the same as woven material. They may be weft or warp knit, single or double mesh, or may be felted or napped or both. Some materials knitted of wool are so heavily napped and are fulled to such an extent that the loop is covered up and is difficult to detect.

Regardless of the method of construction of the cloth, it is important that the manufacturing processes of wool yarn be correctly controlled, as this fiber is sensitive to excessive heat and moisture and is easily injured by contact with chemicals.

Suggestion for the Laboratory

Select and mount samples of woolen and worsted fabrics. These fabrics should include materials suitable for various uses and should illustrate the different methods of construction. Compare the yarns and fibers used in the construction of these materials.

PROBLEM 6. WHAT INFLUENCES THE AMOUNT AND KIND OF WOOL USED?

Today, when dwellings, business houses, schools, theaters—in fact, all buildings in which people gather for business or play—are uniformly heated, the use of wool as a clothing fabric is greatly lessened. The reduction in the amount and weight of wool clothing is noted especially in the United States. There has been practically a 30 per cent reduction in the weight of men's suits and overcoats. Some twenty years ago an eighteen-ounce cloth¹ was used in woolen and worsted

¹ 18 ounces to the square yard.

fabrics for men's wear. Today few cloths over thirteen ounces are produced for this purpose. The wool fabric used for dresses for women and children has shown an even more marked reduction.

In many countries synthetic fibers are blended with wool or used alone in the production of cloth for uses for which formerly it was thought only all-wool fabrics were suitable. In the United States synthetic fibers are blended with wool, sometimes for economic reasons but more often in an effort to obtain new and novel effects. Work is progressing in the attempt to produce synthetic fibers which possess properties that will make them more satisfactory than wool for blankets and carpets.

Australia produces more wool than any other country, and some of it is the best. The 1943 production was reported as 1,164,000,000 pounds.¹ The climate of Australia, which is of a comparatively even temperature throughout, is particularly suited to the raising of sheep. There is an abundant supply of wonderful pasturage together with sufficient water free from excessive alkali. These factors, together with the free open country and high plateaus, had influenced the building up of an exceptionally good wool-producing animal before the importation of the Spanish merinos from the United States, England, and Saxony at the beginning of the nineteenth century. The merino wool produced in Australia is of three distinct grades: fine, medium and coarse. With the growth of the frozen-mutton trade, the tendency in New Zealand and Tasmania is toward the development of the crossbred types. These crossbred wools are, however, among the best Australian wools.

The total world production of wool, on grease basis, for 1945 was 3,760,000,000 pounds! The important wool-producing countries listed in order of amount produced are Australia, Argentina, United States, New Zealand, British South Africa, and Uruguay. The United States stands third in the amount of wool produced, with 387,000,000 pounds, in 1945. The five leading wool-producing states in the United States

¹ *Rayon Organon*, December 1946, p. 189.

WORLD WOOL PRODUCTION BY PRINCIPAL PRODUCING COUNTRIES *

MILLIONS OF POUNDS, GREASE BASIS

YEAR **	WORLD TOTAL		UNITED STATES		AUSTRALIA		ARGENTINA		BRIT. SO. AFRICA		URUGUAY		NEW ZEALAND		ALL OTHERS ***	
	lbs.	per cent	lbs.	per cent	lbs.	per cent	lbs.	per cent	lbs.	per cent	lbs.	per cent	lbs.	per cent	lbs.	per cent
1935.....	3,620	100	428	11.8	971	26.8	365	10.1	238	6.6	113	3.1	304	8.4	1,201	33.2
1936.....	3,720	100	419	11.3	983	26.4	374	10.1	264	7.1	116	3.1	303	8.1	1,261	33.9
1937.....	3,800	100	424	11.2	1,023	26.9	366	9.6	233	6.1	116	3.1	297	7.8	1,341	35.3
1938.....	3,920	100	426	10.8	984	25.1	399	10.2	248	6.3	125	3.2	328	8.4	1,410	36.0
1939.....	4,120	100	428	10.4	1,128	27.4	443	10.8	246	6.0	134	3.2	310	7.5	1,431	34.7
1940.....	4,210	100	437	10.4	1,142	27.1	474	11.3	271	6.4	139	3.3	332	7.9	1,415	33.6
1941.....	4,240	100	456	10.8	1,167	27.5	494	11.7	260	6.1	117	2.8	345	8.1	1,401	33.0
1942.....	4,150	100	459	11.0	1,148	27.7	518	12.5	260	6.3	124	3.0	340	8.2	1,301	31.3
1943.....	4,180	100	450	10.8	1,164	27.8	520	12.4	250	6.0	148	3.6	330	7.9	1,318	31.5
1944.....	3,950	100	418	10.6	990	25.1	500	12.7	234	5.9	142	3.6	373	9.4	1,293	32.7
1945.....	3,760	100	387	10.3	905	24.1	500	13.3	228	6.1	137	3.6	370	9.8	1,233	32.8
1946 ***	3,710	100	358	9.7												

United States Dept. of Agriculture

* Includes both apparel and carpet class wools; includes shorn wool and pulled wool on skins, mostly at shorn equivalent.

** Calendar years for Northern Hemisphere countries; season beginning July 1 and October 1 for Southern Hemisphere countries.

*** Includes Russia and China.

**** Estimated.

¹ Rayon Organon, Dec. 1946, p. 189.

are Texas, Wyoming, Montana, California, Utah, New Mexico, and Ohio.

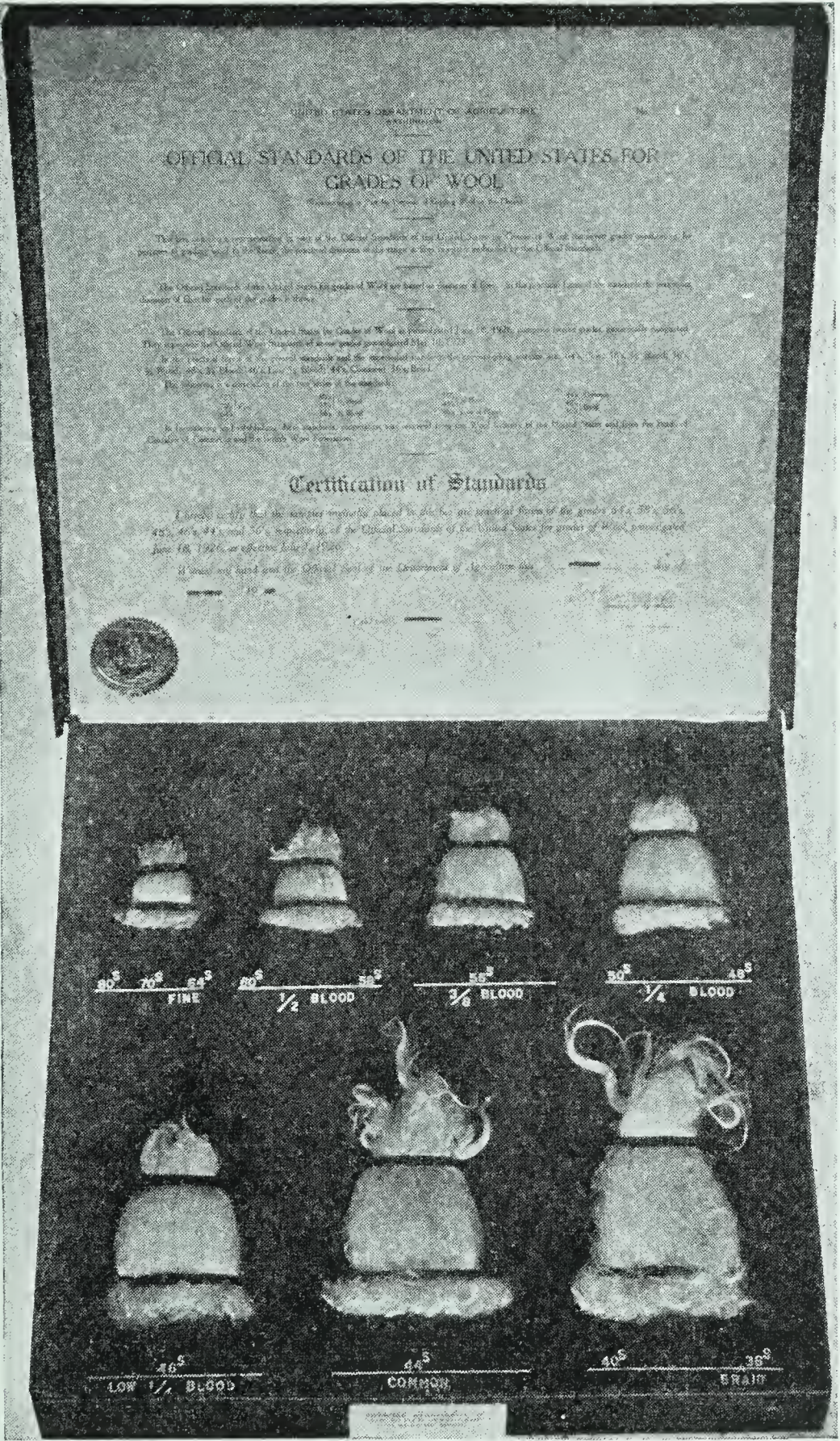
At one time sheep were raised in the United States as much for the wool as for mutton; but today, with the increase of the popularity of mutton and lamb, sheep are being raised on the lambing basis both on the farms and on the ranges. However, the price of mutton is not sufficient to cover the cost of production and give a profit to the producer. The quality of the mutton cannot be sacrificed in order to produce coarse wool, nor will the sheep that can be raised in large numbers on the range produce this coarse fiber. The flocking or gregarious instinct is an essential characteristic of sheep to be handled on the range, and this instinct is characteristic of fine-wool sheep.

The manufacturing processes may call for wool of different grades in varying amounts from those that are produced locally, or the costs may make the use of the imported fiber economically desirable. With an increased demand for domestic wool there is a corresponding rise in price. If the importation of wool becomes difficult due to conditions abroad, there is an increase in the amount of wool produced in the United States.

South Africa produces a wool which is extensively used for hosiery and knitting yarn. It scours a good white, has excellent spinning quality, and is soft, but does not possess good felting qualities because of the hardness of the epidermal scales. The difference in the care given the sheep in Africa results in wools which vary greatly in quality. Asiatic wools include some of the best grades for carpets and coarse woolens. The Asiatic herds were developed from the wild sheep of the Asiatic mountains, and have retained the characteristics of the undomesticated animals. The quality of these carpet wools varies from the finest to the coarsest.

South American wools are of good quality; the sheep are a crossbred type which has been developed from Spanish merino.

The leading importers of wool are France, the United Kingdom, and the United States. The United States produces a greater portion of the amount it consumes than any of the



Courtesy Bureau of Agricultural Economics, U. S. D. A.

Official standards of the United States for grades of wool.

other wool-manufacturing countries. The leading wool markets of the world are the following:

England	London and Liverpool
Australia	Sydney and Melbourne
United States	Boston, New York, and Philadelphia

Can you explain why these cities are the chief wool markets?

PROBLEM 7. OF WHAT IMPORTANCE ARE SPECIALTY FIBERS?

Although all animal fibers resemble each other in their physical properties, their individual characteristics determine the use that can be made of them and therefore their commercial value. The stiff bristles of the hog, in contrast to the soft, silky fibers of the vicuna, are an example of the great difference in their texture. A study of the longitudinal and cross sections will show a wide range in the size of the fibers and types of scales. The size and shape of the medulla are characteristic of fibers from certain animals and serve as the best method of identification.

Fibers of the Angora goat (mohair), the llama, alpaca, camel, vicuna, and rabbit are used alone or in connection with other fibers in clothing and household fabrics.

Mohair. The importance of mohair, the product of Angora goats, in the United States is shown by the fact that 22,200,000 pounds were clipped in 1945. Texas led in the amount of mohair produced, having had 91 per cent of the total. (See page 222.) Missouri, New Mexico, Arizona, Utah, Oregon, and California followed in order of amount produced.¹

The mohair fiber is white in color. It is long, lustrous, fine, and strong and possesses excellent spinning qualities. The scales are somewhat pointed and partially overlap. In general, the surface of mohair is smoother than that of wool.

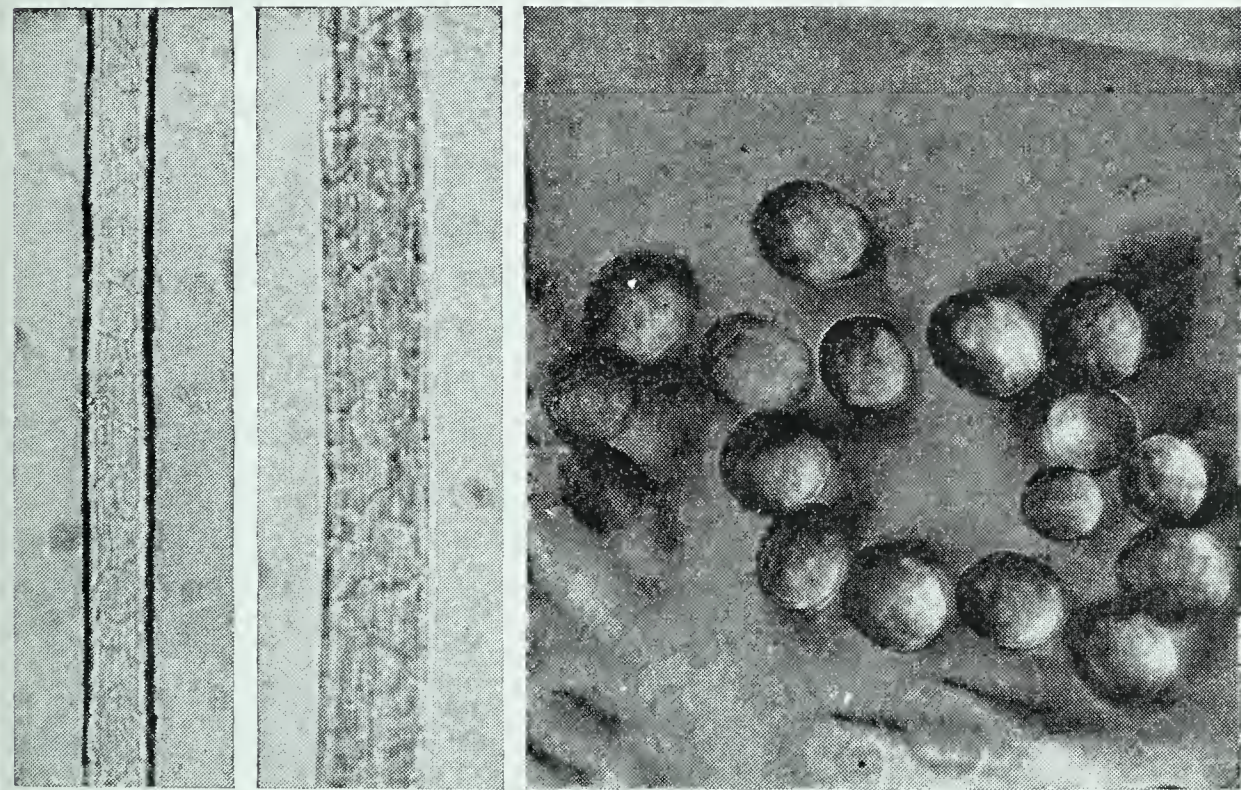
Mohair will absorb from 25 to 30 per cent of its weight in

¹ "Mohair for Superior Performance," *Mohair*, American Wool Council, Inc.



Courtesy Division of Range Animal Husbandry, Texas Agricultural Experiment Station

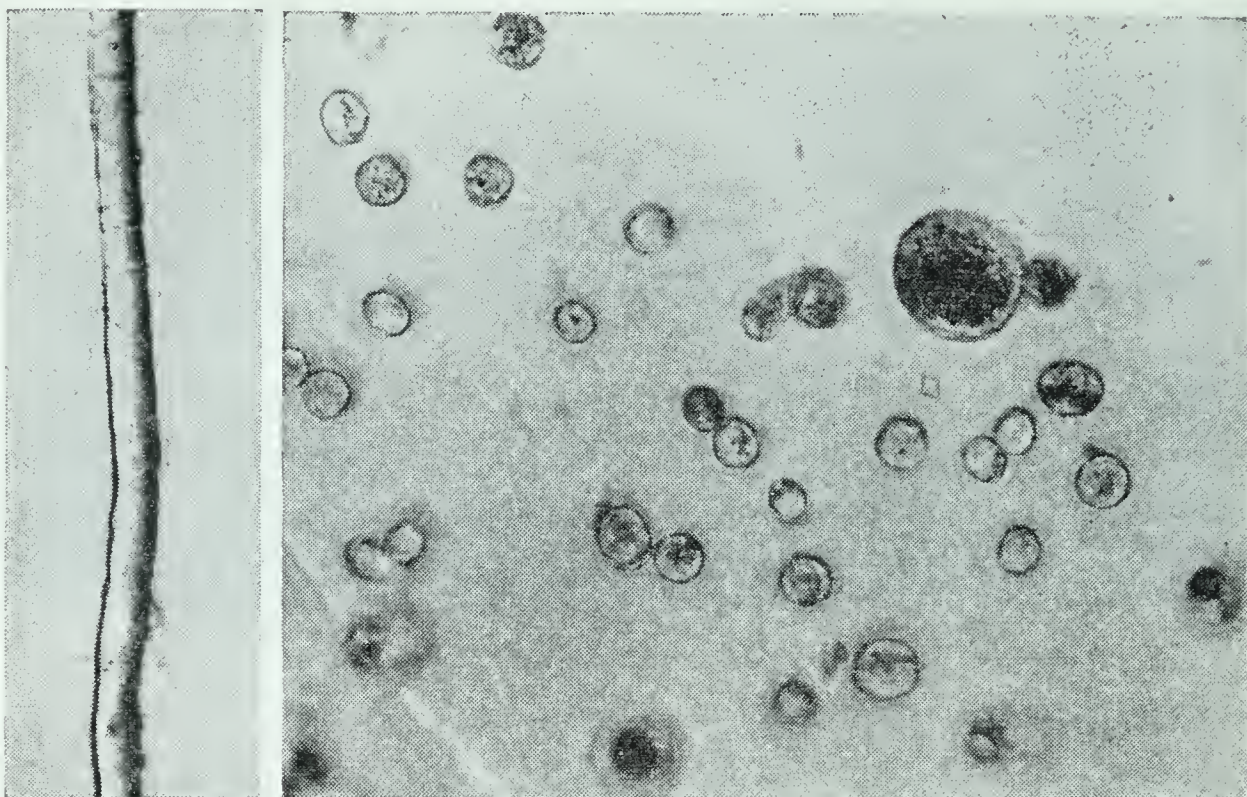
Angora goats on Texas farm.



Longitudinal and cross section of mohair fiber.

moisture without feeling wet. Fine mohair lacks a medulla but it is frequently present in coarse fibers. One year's growth of mohair per goat is about $3\frac{1}{2}$ to 5 pounds. The fleece is usually clipped twice a year.

Mohair lacks the felting property of wool, which limits its



Longitudinal and cross section of cashmere fiber.

use somewhat. It is used largely in the manufacture of upholstering material, men's summer suits, and lining material. It also finds use in trimmings, braids, hats, and pile fabrics. Probably the most valuable use of the long mohair fibers is in the manufacture of wigs and switches for theatrical purposes. Rugs made of mohair compare favorably in durability and appearance with handmade Oriental rugs.

The leather from the pelts of the Angora goat is used in the manufacture of gloves, purses, and novelties. The meat of the goat has considerable value to the producers.

Cashmere goat. Another goat important for its hair covering is the cashmere goat, which is native to Tibet and northern India. (See page 225.) These animals have two distinct coats—the long, straight, coarse outer hair and the fine, silky undercoat which is the cashmere fiber. This fiber is used to a limited extent in some of the finest wool fabrics.

Camel hair. Camel hair is found in many coat and dress materials. It may be used alone but is more often mixed with other fibers. The Bactrian camel with two humps is the source of the fiber used for textiles. This fiber has unusual

insulating properties which give it the special warmth qualities for which it is noted. The climate of Tibet where the camel lives is extremely hot in summer and cold in winter, and the fiber covering of these animals possesses the qualities which protect them from these extremes.

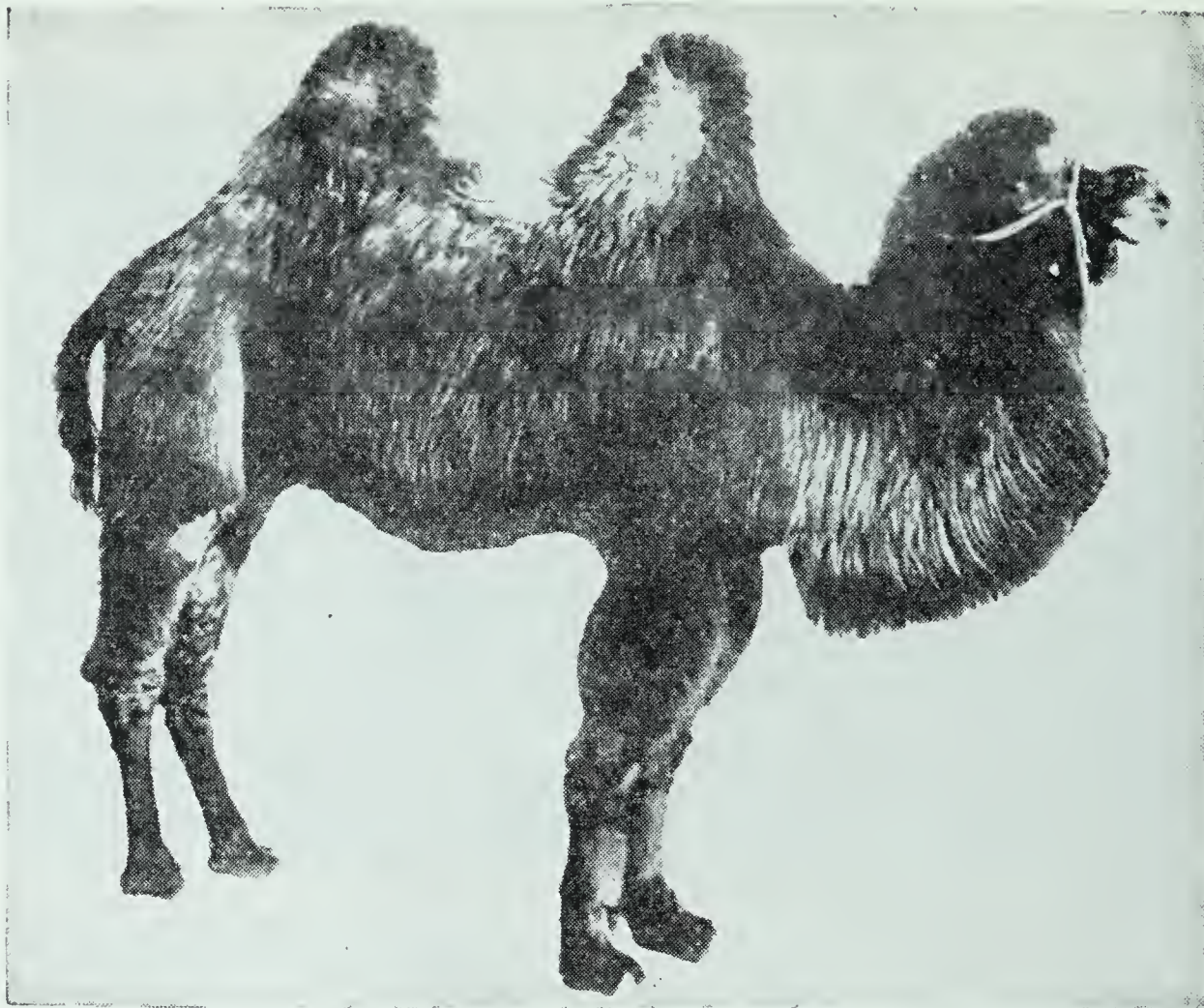
The camel sheds its hair which becomes matted and hangs in strands and tufts from all parts of the body and these matted fibers fall off in clumps. These are picked up by a man known as a trailer who follows the caravan. Camel hair varies in fineness and quality more than any other fiber. The coarse fleece yields extremely poor fibers but those of the fine fleece are beautiful and fine. The outer hair is coarse, tough, and wiry. Under this is a layer that is much better in quality but not desirable. The inner short fiber is really little more than down. This fine fiber is light tan in color and very soft and lustrous. However, it has great tensile strength. It is the true camel hair fiber which for years has been made into extremely beautiful camel hair cloths. However, sometimes the coarser fibers are used in cloth which is much less beautiful in texture. The No. I quality, which forms the inner coat, is sometimes combed to remove its coarser hairs, leaving only the very finest fibers, known as "noils." These extremely fine fibers are seldom used alone but are blended with No. I quality.

The insulating properties of camel hair are due to its structure. The structure of camel hair resembles that of wool, consisting of three layers of cells. The inner, a medullary layer or canal, is very small and often noncontinuous in fine fibers. This canal includes the pigment and air cells. The finer the



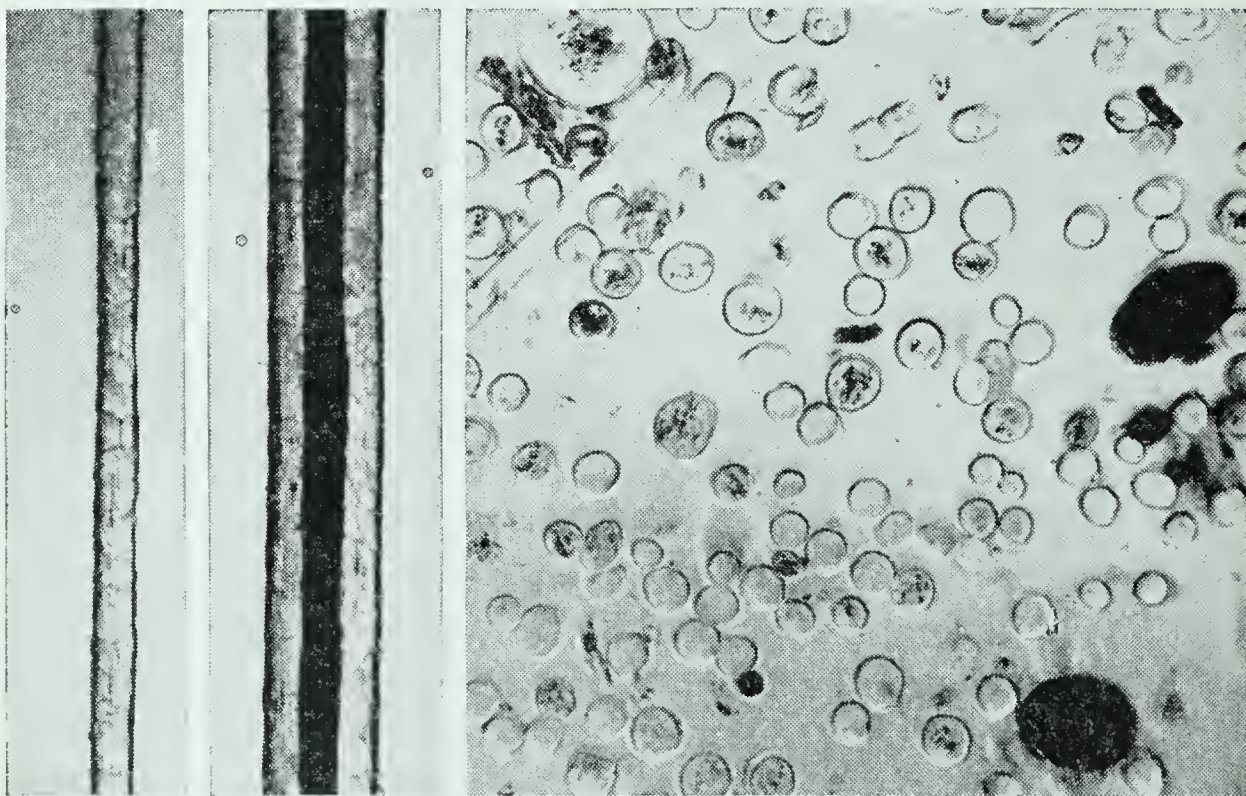
Courtesy S. Stroock and Co.

From Tibet and the high mountains of India comes the fleece of the cashmere goat.



Courtesy S. Stroock and Co.

The Bactrian camel, whose hairy coat provides a popular type of coat material.



Longitudinal and cross sections of camel fiber.



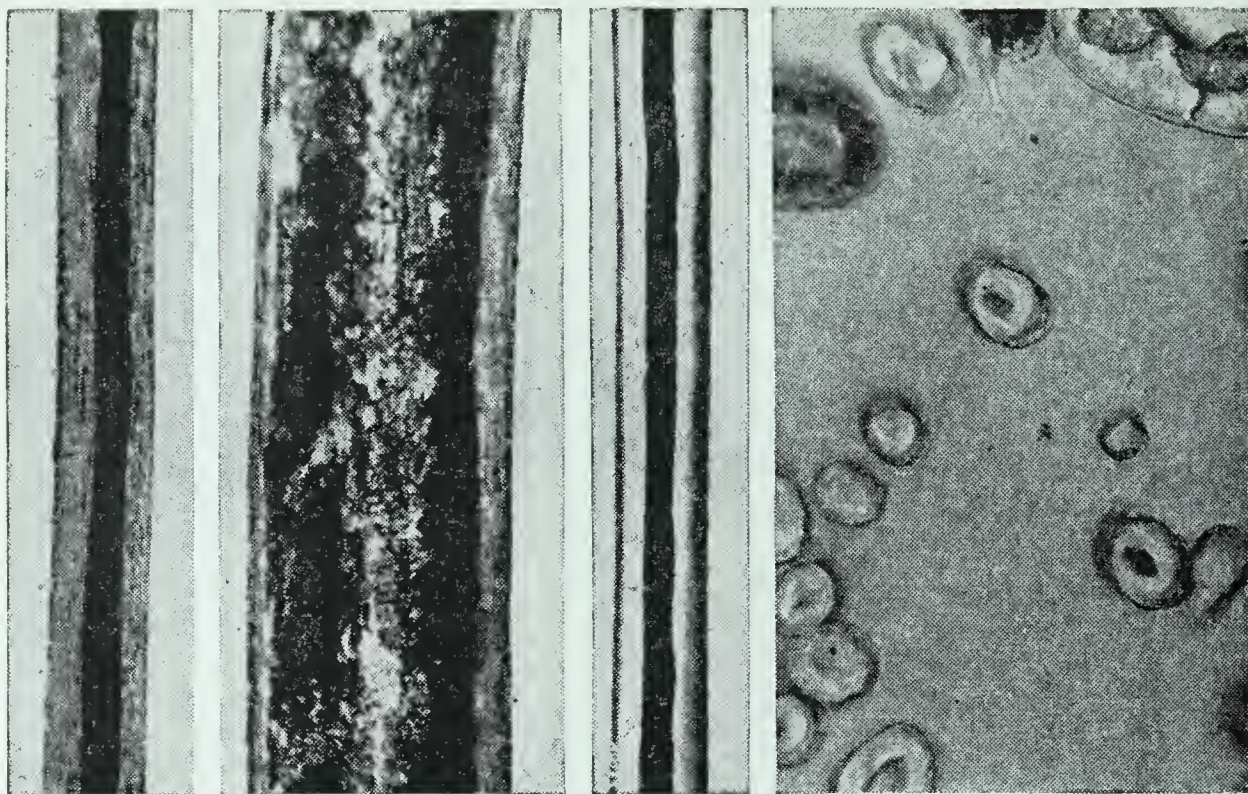
Courtesy American Museum of Natural History

Llamas of the Andes. Fibers from these animals are sometimes made into cloth, so valued that it is now widely imitated.

fiber the greater number a fabric would contain and the correspondingly larger portion of air spaces between fibers. The proportions of air in a yarn or fabric determine its insulating power.

It has been estimated that the price of a hand-woven camel hair fabric produced by the ancient Chinese would be equal to \$100 a yard today. In normal times fabrics of even more beautiful quality sell for \$9.00 per yard.

The llama. The llama, an aristocratic member of the camel family, is valuable as a fur-bearing animal and is also a beast of burden. Although llamas will refuse to carry more than a



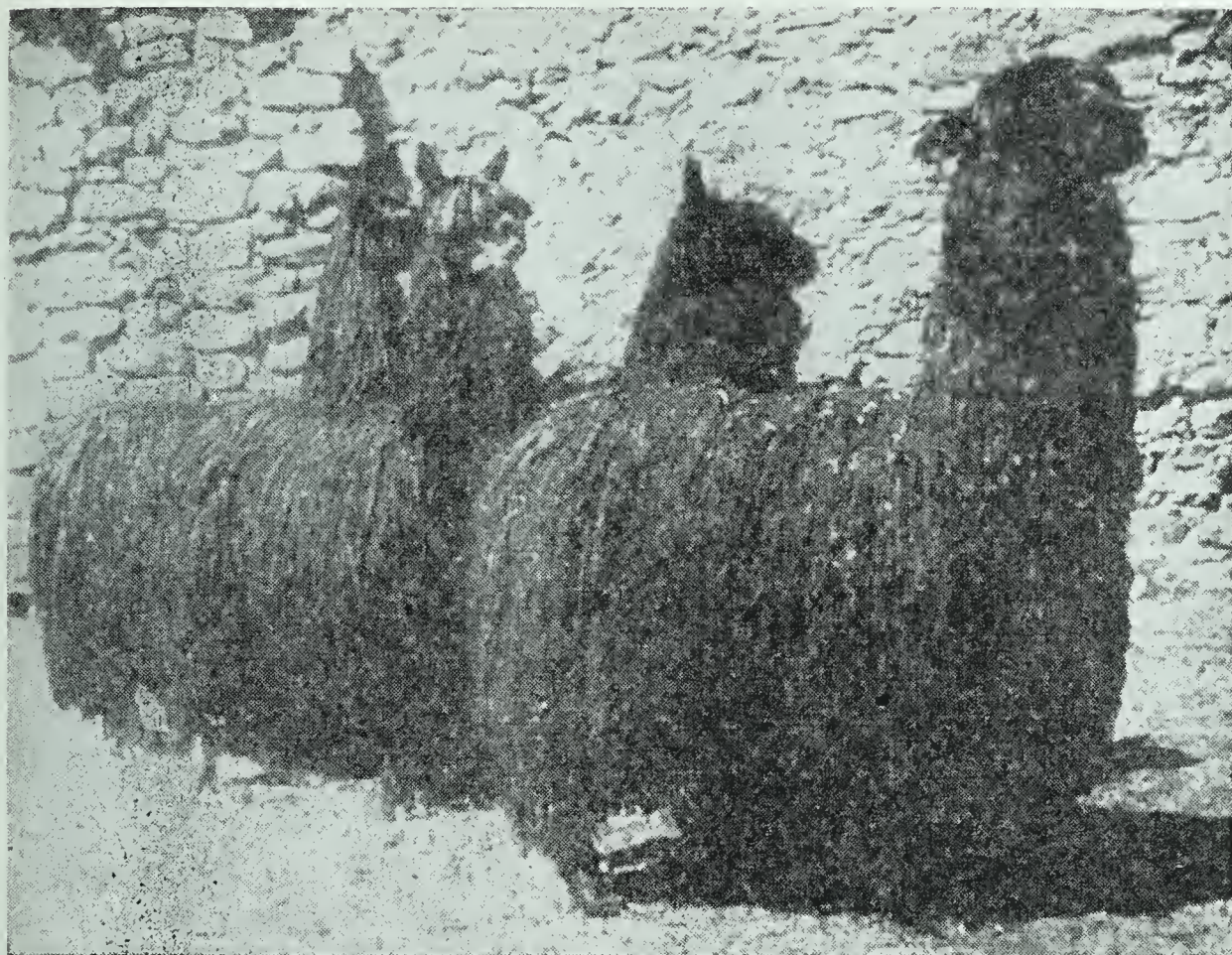
Longitudinal and cross section of llama fiber.

limited number of pounds, they are used in many instances because it costs nothing to feed them and because their hair is valuable as a textile fiber. (See page 227.)

There are four distinct and two hybrid species of llamas. All of these occur in the Pacific Coastal regions of South America. The llamas and alpacas are the domesticated species; the guanaco and vicuna, the wild species. The natural habitat of the llamas is the high ranges of southern Ecuador, Peru, Bolivia, and northern Argentina. The entire body of the llama is covered with a thick coat of long hair. The outer coat of the llama is coarse but the hair next to the body is fine, resembling that of the alpaca. The llama's fleece is brown in color, varying from almost white to black.

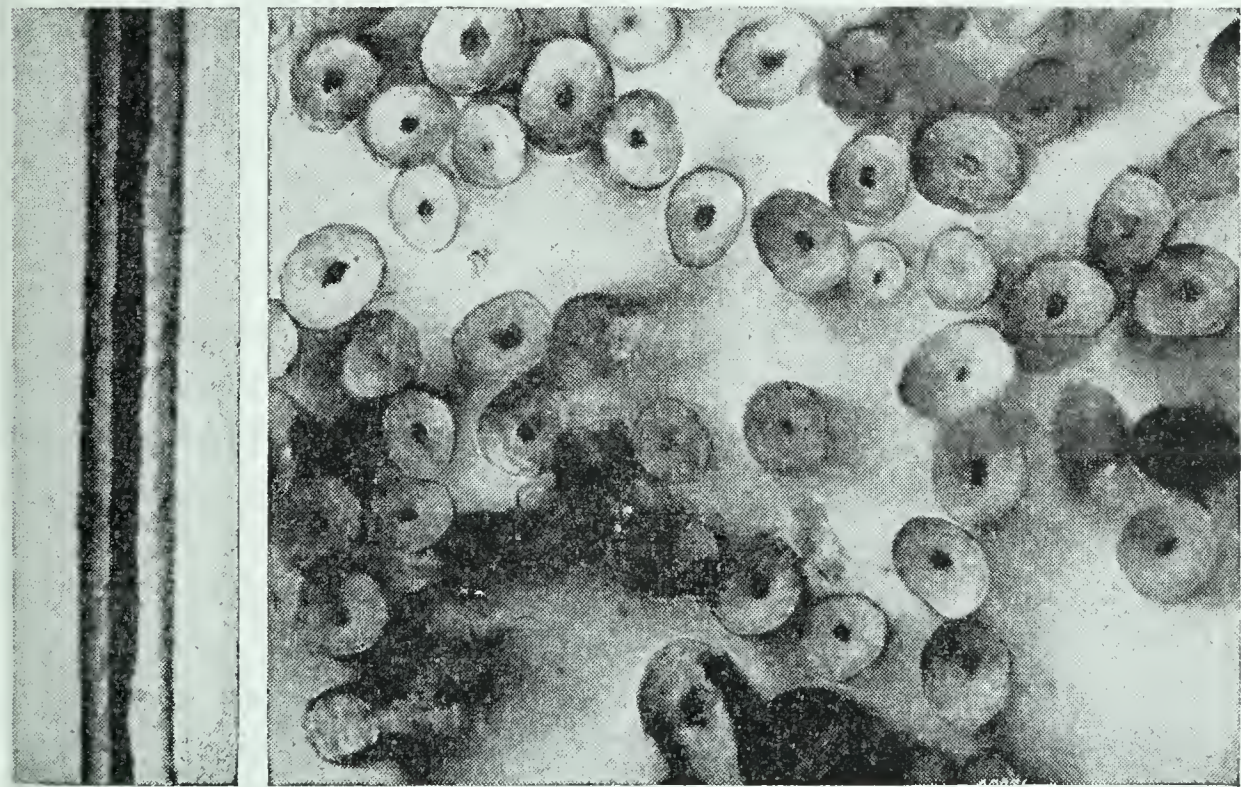
A day's journey for a llama is from 15 to 20 miles. The animal must be permitted to stop and graze frequently as it will not eat at night.

The alpaca. The alpaca is another member of the camel family which furnishes a fiber of commercial value. Both llama and alpaca fibers are similar to mohair in character. Alpaca fiber constitutes a large portion of wool fibers, other



Courtesy "Fleece from Other Backs," by Fred Grove-Palmer, *Textile World*, Vol. 78 (1930), p. 1121

Alpacas.



Longitudinal and cross section of alpaca fiber.



Courtesy S. Stroock and Co.

The vicuña, producer of our finest, softest wool fiber.

than sheep, appearing on the market. Through breeding, the hair fibers have become even in quality and the undercoat has disappeared. Both llama and alpaca fibers occur in the natural colors of white, gray, fawn, brown, piebald, and black. (See the illustrations on page 229.)

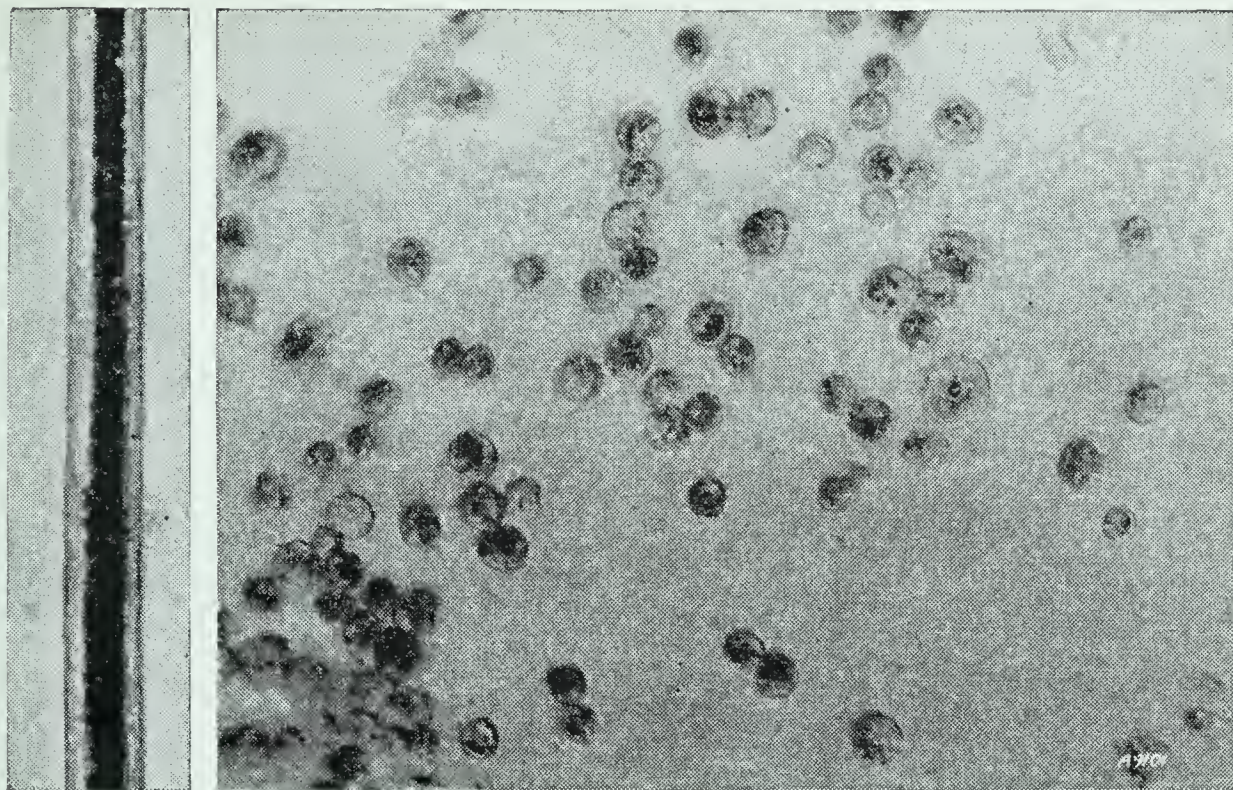
The hair of the alpaca hangs over the body of the animal, sometimes completely concealing the feet. The fibers measure from eight to twelve and even sixteen

inches in length. The fleece is sheared every two years and weighs from four to seven pounds. The alpaca fibers are coarser than those of the vicuña or the camel. The fibers are more often medullated and are more uniformly pigmented in the alpaca fiber than in those of the other animals. The fibers of the alpaca and the finer fibers of the llama are closely allied to true hair fibers. Alpaca fibers have a higher luster than most other animal fibers.

Llama garments made from the fibers of any member of the family, including alpaca and vicuña, are produced in the natural colors either alone or ingeniously blended. This method enables the manufacturers to preserve the excellent softness of texture and high luster of the original fibers.

Vicuña. Vicuña is a third member of the camel family which is important for its fibers. Vicuña wool is the finest, softest animal fiber utilized for textiles. (See picture above.)

Together with softness and fineness the vicuña fiber possesses great luster, tensile strength, and beauty. It is extremely resilient and elastic and possesses great surface cohesion. The



Longitudinal and cross sections of vicuna fiber.

vicuna fiber is less than one two-thousandths of an inch in diameter. These silky hairs show little evidence of medulla and the coloring matter is evenly distributed. As in other animals of this group the vicuna possesses an outer and inner covering. The outer hair is coarse and really a protective covering for the inner soft silky fleece. The vicuna is a small, wild animal that cannot be domesticated and cannot be captured alive. Only about one-fourth pound of the inner hair is obtained from a single animal. The fibers from about 40 animals are required for one coat. Because the fiber is so difficult to obtain it is very expensive, one yard of cloth costing from \$90 to \$200.

No coloring is needed to enhance the beauty of the vicuna fibers and they are generally used in their natural state.

Other fibers of importance. Fur fibers are now being used in novelty fabrics. The most important of these are the Angora rabbit and the common rabbit. Fibers of the muskrat, beaver, raccoon, and squirrel are also used. Hair fibers of minor importance—those of the hog, cow, horse, and even human hair—are only occasionally used in the construction

of cloth. Hairs of this type are used in novelty fabrics to obtain some specific effect.

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Unit Three

SILK, THE QUEEN OF FABRICS

THE characteristics of silk, which have made it the queen of fabrics for many centuries, have never been equaled in any other material. The beauty and elegance of this fiber will prevent it from disappearing from the textile field.

The temporary stoppage of the production of silk in the Orient revived interest in experimental production in the United States and in England. If the present attempts in these countries to improve, simplify, and more fully mechanize the handling of the silk fiber from the cocoon to the cloth are successful, it may make the production of silk in the United States and England practical from an economic standpoint.

The production of the silk fiber has been for centuries one of the chief industries of the Orient, especially Japan. According to legend, the beginning of the history of the use of silk as a textile fiber goes back to 2600 B.C., when the fourteen-year-old wife of the Chinese Emperor, Huang-Ti, discovered the secret of drawing out the filament from the cocoon of the silkworm and producing a fabric from this filament. This young princess, Si-Ling-Chi, is known as the "Goddess of the silkworms" and is today the center of religious ceremonies connected with the care of the silkworms and the production of silk.

In Japan, where the production of silk has long been an important factor in the economy of the empire, it was the Sun Goddess, according to tradition, who first cared for the silkworms and produced the silk fiber. She later entrusted its development to a young princess. Here too, religious ceremonies have always been connected with the raising of the silkworms.

According to some authorities, the production and manufacture of silk remained a secret with the imperial family of China for more than two thousand years. Silkworm eggs were taken to Japan by two priests who hid them in their hollow bamboo staffs. The raising of silkworms and the production of the silk fiber gradually spread throughout much of the world from Japan.

Japan has been for years the most important silk-producing country, furnishing more than 60 per cent of the world's supply of raw silk.

PROBLEM 1. HOW IS SILK PRODUCED?

The following discussion of the production of silk as it has been carried on in the Orient from early times pictures an industry that developed from very simple primitive methods to one scientifically controlled.

The one source of the silk fiber is the cocoon spun by the silkworm, which is a species of caterpillar. (See page 239.) There are several species of silk-producing caterpillars, but the mulberry silkworm, or *Bombyx mori*, produces most of the commercial fiber. These mulberry silkworms have been cultivated for many centuries. There are other associated varieties which live upon the scrub oak and produce the fiber known as wild silk. Wild silk varies greatly as to quality, and as a whole is coarser, more uneven, and more difficult to handle than the fiber produced by the cultivated worm.

The industry has always been divided into four independent parts: sericulture, reeling, throwing, and manufacturing. The production of the mulberry trees and the gathering of the leaves to be fed to the silkworms is an important phase of the industry.

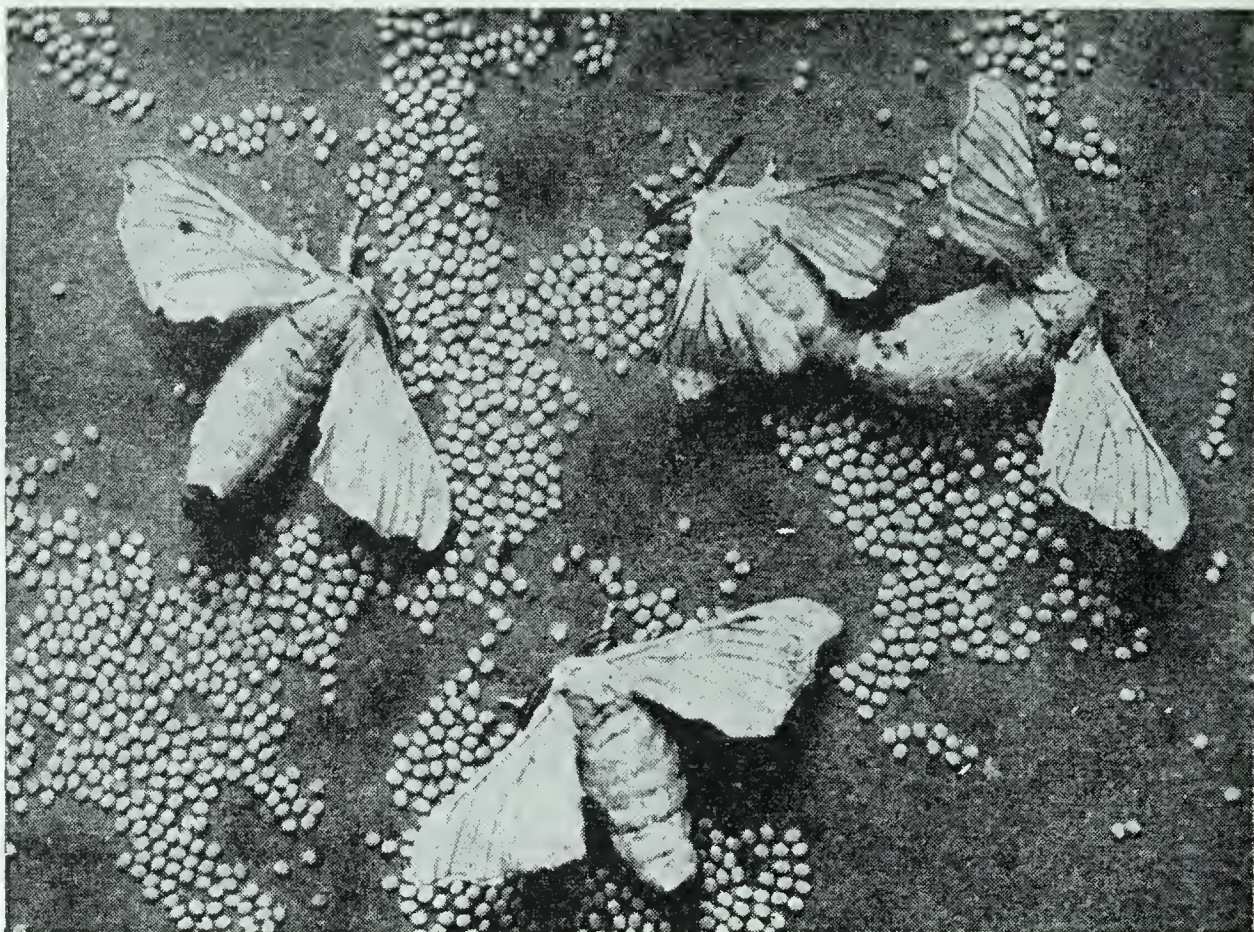
Sericulture. Sericulture consists of the production of the worms, their care during development, and the spinning of the cocoon. The silkworm passes through four stages of development: the egg, caterpillar, chrysalis, and moth. These four stages, together with the time which elapses between them, probably aided the Chinese in keeping the production of silk



Silk-producing caterpillars, full grown.

a secret for so many years. Sericulture begins with the laying of the eggs, which are so tiny that they are often spoken of as seeds. The eggs are deposited by the female moth upon a cloth or paper prepared for this purpose.

The ancient Chinese dried the eggs carefully and then handled them in many and various ways to prevent their hatching until the next spring. When the leaves began to sprout on the mulberry trees, the eggs were covered with blankets or carried next to the body to supply the necessary amount of heat for hatching. As soon as the worms were hatched the young, tender mulberry leaves were gathered and shredded for their food. These shredded leaves were sprinkled over the tiny worms, and the bits of leaves with the worms clinging to them were carefully lifted and transferred to the feeding trays. Any worm that was too weak to crawl was discarded. The careful, tedious work of caring for the worms was done by women and children. The temperature of the room had to be controlled, the food kept dry, the trays clean, and the worms fed five or



Courtesy The Silk Association of America, Inc.

The laying of eggs from which silkworms are hatched.

six times a day. The leaves had to be kept fresh, dry, and neither too hot nor too cold.

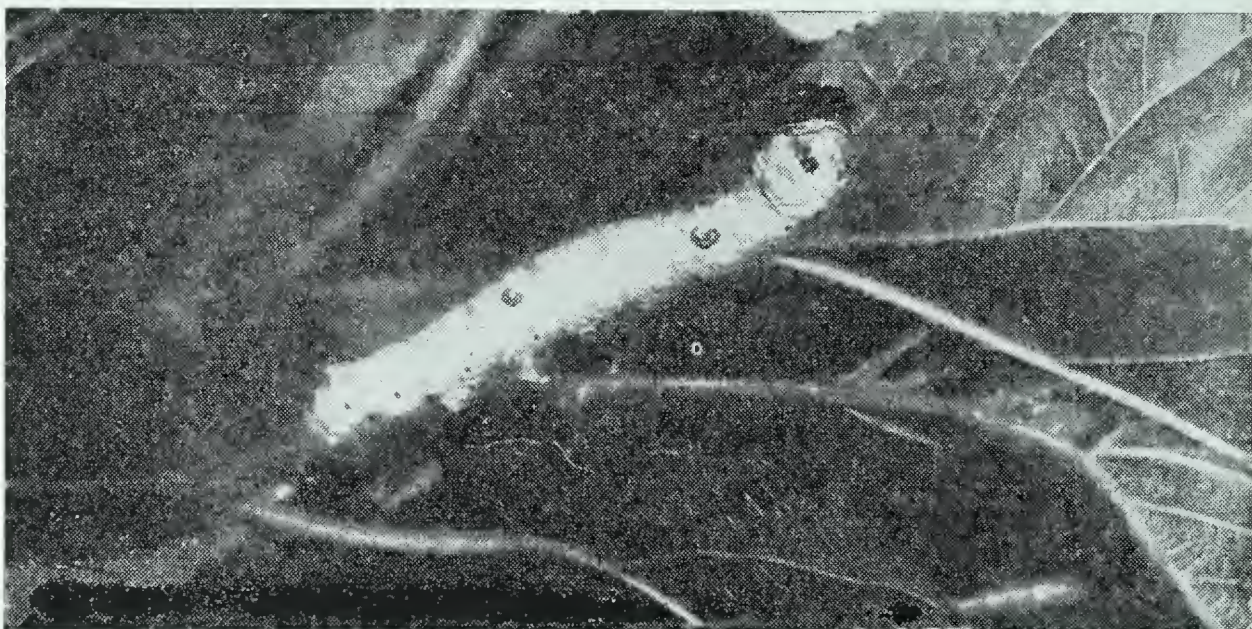
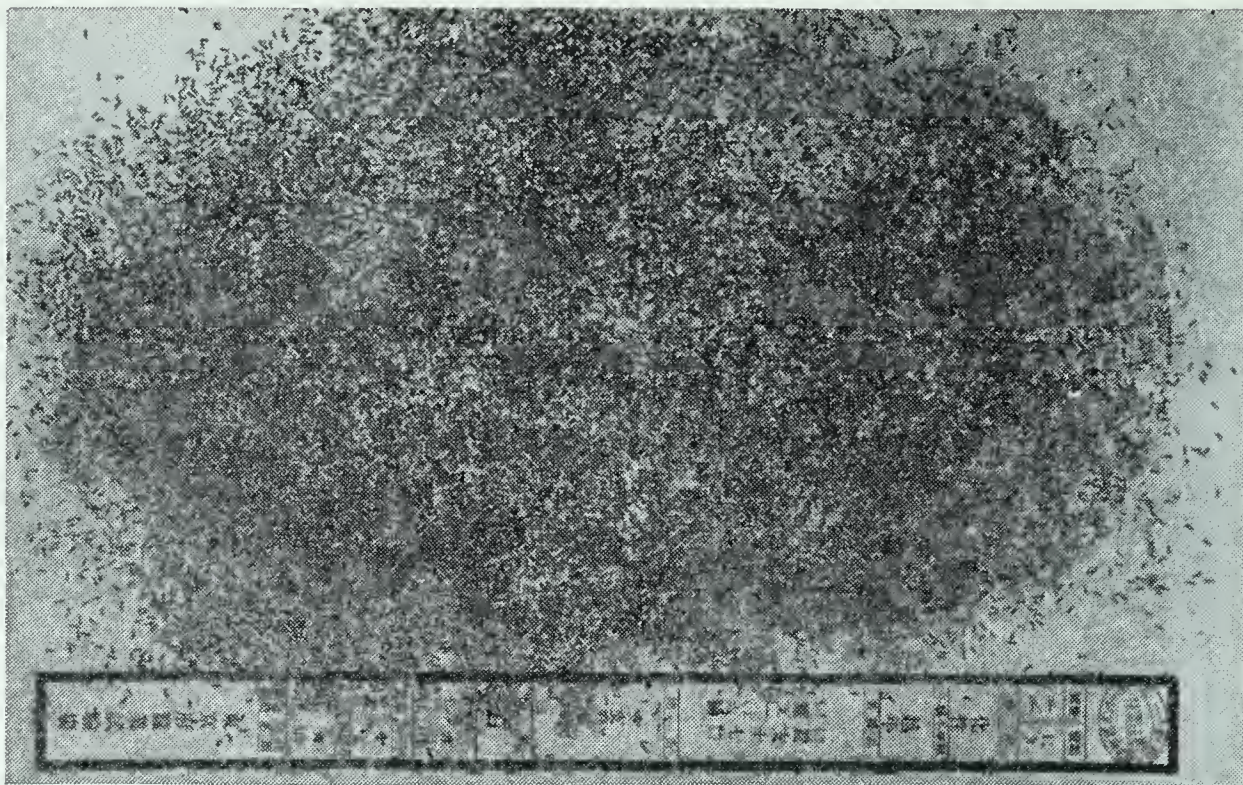
In recent years silk culture was carried on in the homes of the Chinese and Japanese farmers by methods quite similar to those used in ancient times. Silk farming was at one time "the whole or partial livelihood of 40 per cent of Japan's agricultural population"¹ of over ten million people. About one-fourth of the farm land was required for the raising of mulberry trees, which produced the sole food of the cultivated silkworms. (See page 237.) A large number of workers, principally women and girls, were employed in the various divisions of the large silk industries of Japan.

Officially approved silkworm eggs were delivered to the farmers by the Japanese Agricultural and Forestry ministry. These eggs were produced according to government specifications and according to tradition the worms used were de-

¹ "Silk," *Fortune*, Vol. 11, No. 3 (1935), p. 74.



Top, gathering mulberry leaves for the silkworms. Bottom, feeding the worms and cleaning the trays.

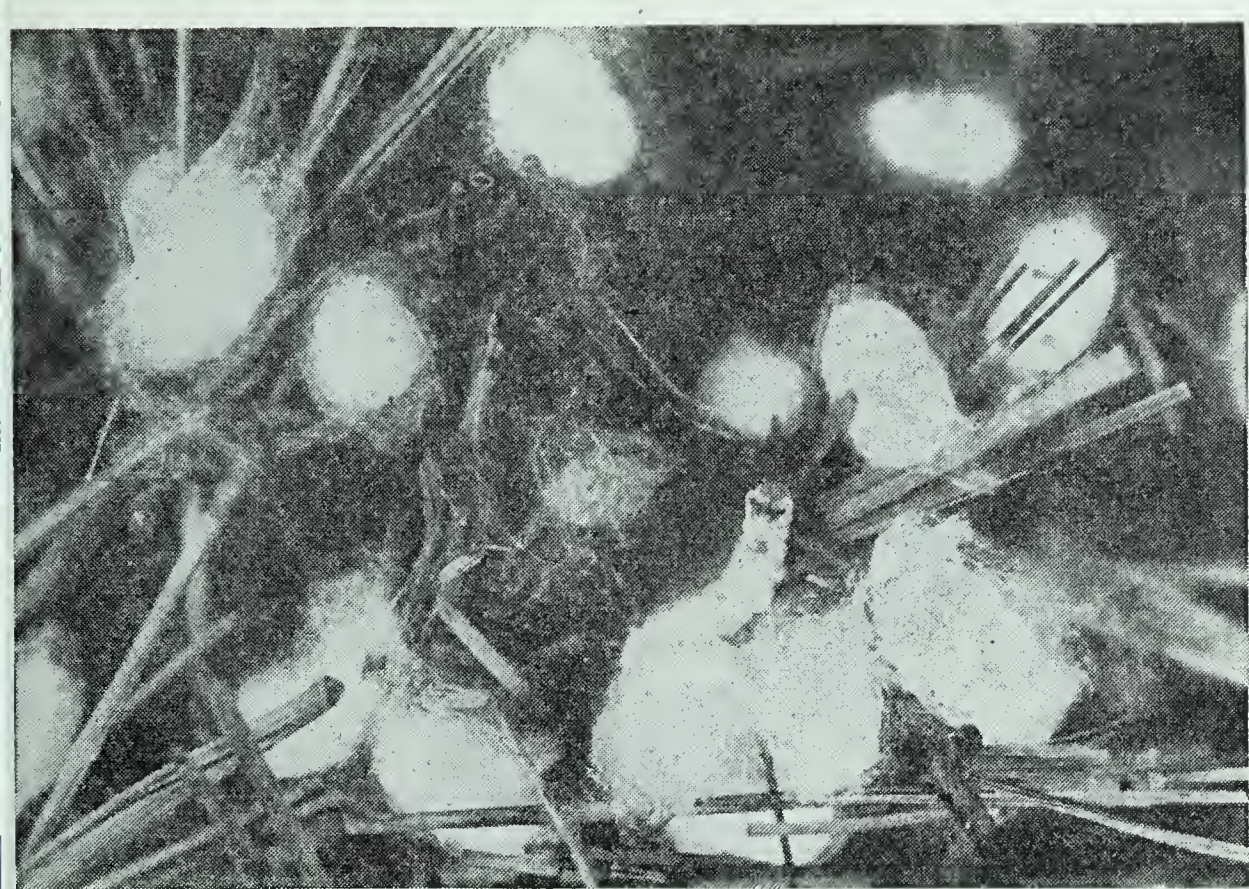


Courtesy Central Silk Association of Japan

Top, newly hatched silkworms. Bottom, full-grown silkworm. Note the contrast in size and color.

scendants of worms kept at the imperial palace. No other eggs could be used; thus the government was able to control the amount and quality of cocoons produced.

The newly hatched worm is about three millimeters long, almost black in color, and weighs approximately .005 gram. (See page 238.) The picking and shredding of the fresh mul-



Trellis of bamboo and rice straw in which the cocoons are spun. Note the net or web about each cocoon and the one silkworm just beginning its spinning.

berry leaves for the newly hatched worms require the combined labor of the women and children of the household. Only the tenderest, young leaves can be fed to the young worms. If the leaves are wet, they must be wiped dry. Fresh leaves must be supplied every few hours and the trays kept clean. The temperature and humidity of the room where the worms are feeding must be controlled.

During its growth the silkworm passes through four sleeping or resting periods in which it ceases to eat. These are followed by molting, when the worm sheds its already outgrown skin. During the feeding periods it eats continuously and grows rapidly. The fully developed worm is milky white in color and has increased its weight approximately ten thousand times. It ceases to eat and lifts its head in search of something on which to spin its cocoon. If a trellis of bamboo and rice straw is built and the worm placed on it, the worm first spins a net or web, then forms a case or shell known as a co-

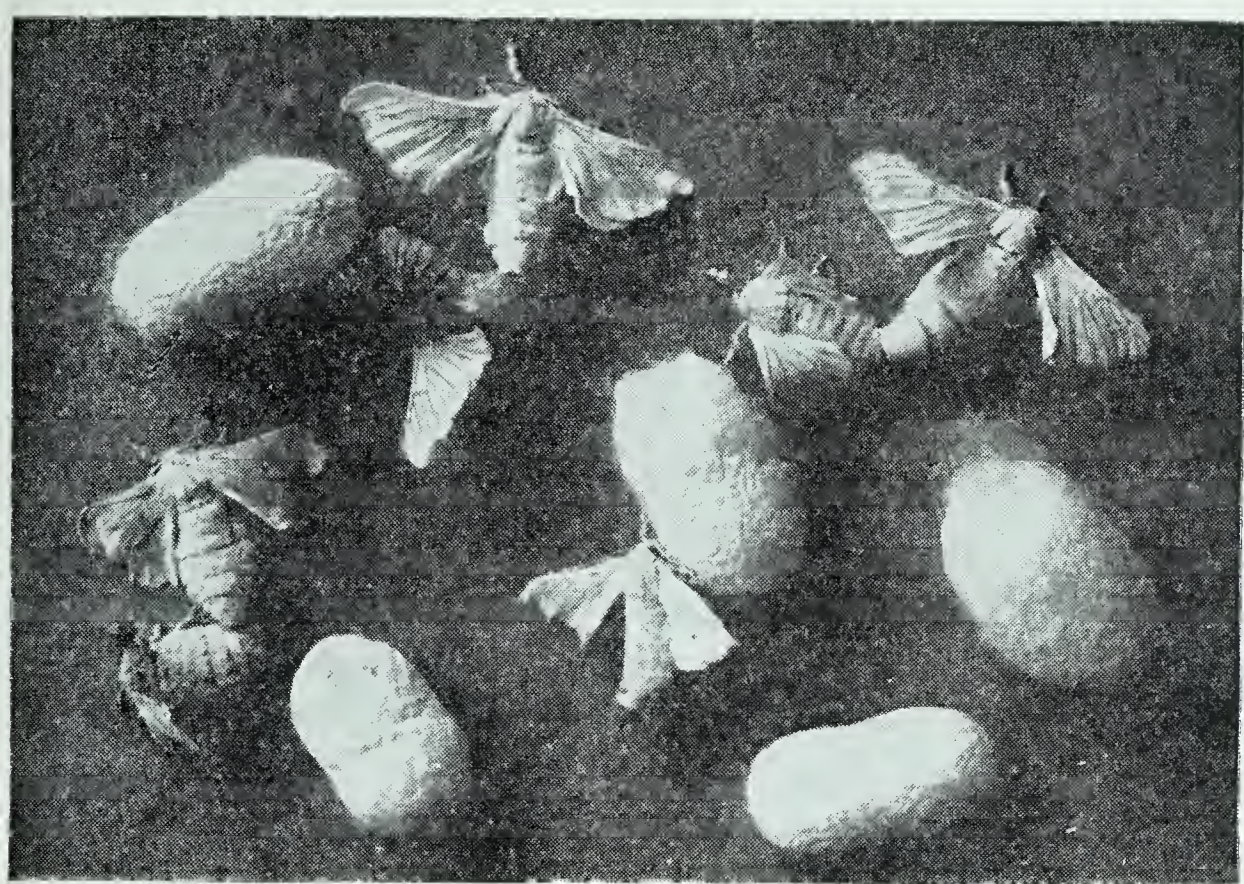


Courtesy The Corticelli Silk Co.

Silkworm chrysalis—twice actual size.

coon. To do this it doubles itself on its back, with its feet on the outside, and with many movements of its head spins the cocoon by secreting a viscous fluid produced by two glands in the body. This fluid solidifies on contact with the air and forms a double strand of silk fiber. At the same time a gum known as *sericin* is secreted, which cements these two filaments of silk together. The silkworm makes more than one movement of its head each second, and some 300,000 turns are required to spin the cocoon, which is built up of many layers of silk fiber spun back and forth in the form of the figure eight. After the worm can be seen no longer it can still be heard working away within the cocoon, which is completed in two or three days. When the cocoon is finished, the caterpillar changes into the pupa or chrysalis. (See illustration above.) This is the third stage of its life cycle.

If the chrysalis is not destroyed, a moth develops in about two weeks. This moth secretes an alkaline solution which so weakens the fibers that they are easily broken and it can push its way out at the bottom of the cocoon. (See opposite page.) Though this part is less dense than the remainder, many strands of silk are broken to permit the escape. The mother moth usually moves but a few inches and spends practically



Moths after emerging from the cocoon. The opening forced by the moth through the end of the center cocoon can be seen distinctly.

her entire life, of only a few days, laying eggs. One ounce of eggs will produce from 100 to 150 pounds of cocoons.

With the slow and tedious methods used in ancient times to remove the silk from the cocoons, it was impossible to handle more than a small portion of them before the moth developed and emerged, thereby breaking the long, continuous strands. The discovery of an effective method for killing the chrysalis without injuring the silk fiber was an important step in the production of silk. For this purpose the cocoons were sometimes salted down in air-tight vessels, or they were exposed to the hot rays of the sun. Later the chrysalis was killed by steaming the cocoons and then drying them before they were stored for future use. Cocoons are sorted today on the basis of quality, before being offered on the market. (See page 242.)

Sericulture is carried on by highly specialized methods for two distinct purposes: first, the production of disease-free eggs for breeding; second, the production of raw silk for use



Top, sorting and weighing cocoons in preparation for the market. Bottom, hand reeling of silk in the home. A pan of hot water placed over a charcoal burner affords a means of softening the gum.



Courtesy "Japan News-Week"

Top, farmers taking cocoons to the auction. Bottom, auction table with auctioneer in center and voting tablets in front of him. Cocoons are on a revolving table passing in front of the bidders.

in the industries. Raising worms for the production of silk when carried out on a large scale requires well-equipped establishments. Here the eggs are kept in cold storage until the desired time for hatching, when they are placed in incubators. The rooms where the worms are kept are scientifically maintained at constant relative humidity and temperature.

Under the supervision of the Japanese government, establishments conducted by experts are maintained for the production of disease-free eggs. These eggs are distributed to the farmers for use in the production of silk for the trade. This method has been adopted in order to prevent and control diseases to which the worms are susceptible. Evidence of disease is detected by a microscopic examination of the mother's body. If a moth shows any signs of infection all her eggs are destroyed. Research has shown that the feeding of diseased mulberry leaves results in unhealthy worms. The application of scientific methods to breeding and to the control of disease has resulted in stronger, more healthy worms, able to produce stronger, more even, perfect fibers.

In ancient times there was but one annual crop of silkworms, but today there are the spring (May-June), summer (July-August), and fall (September-October) crops. The mulberry trees are trimmed back after the spring crop of worms has started spinning and the new shoots furnish fresh tender leaves for the second crop. By this method the trees are kept small, really not more than bushes, and fresh, tender leaves are made available for the three crops of worms. In the fall the mulberry trees are carefully pruned and the branches tied together to protect them from the winter storms.

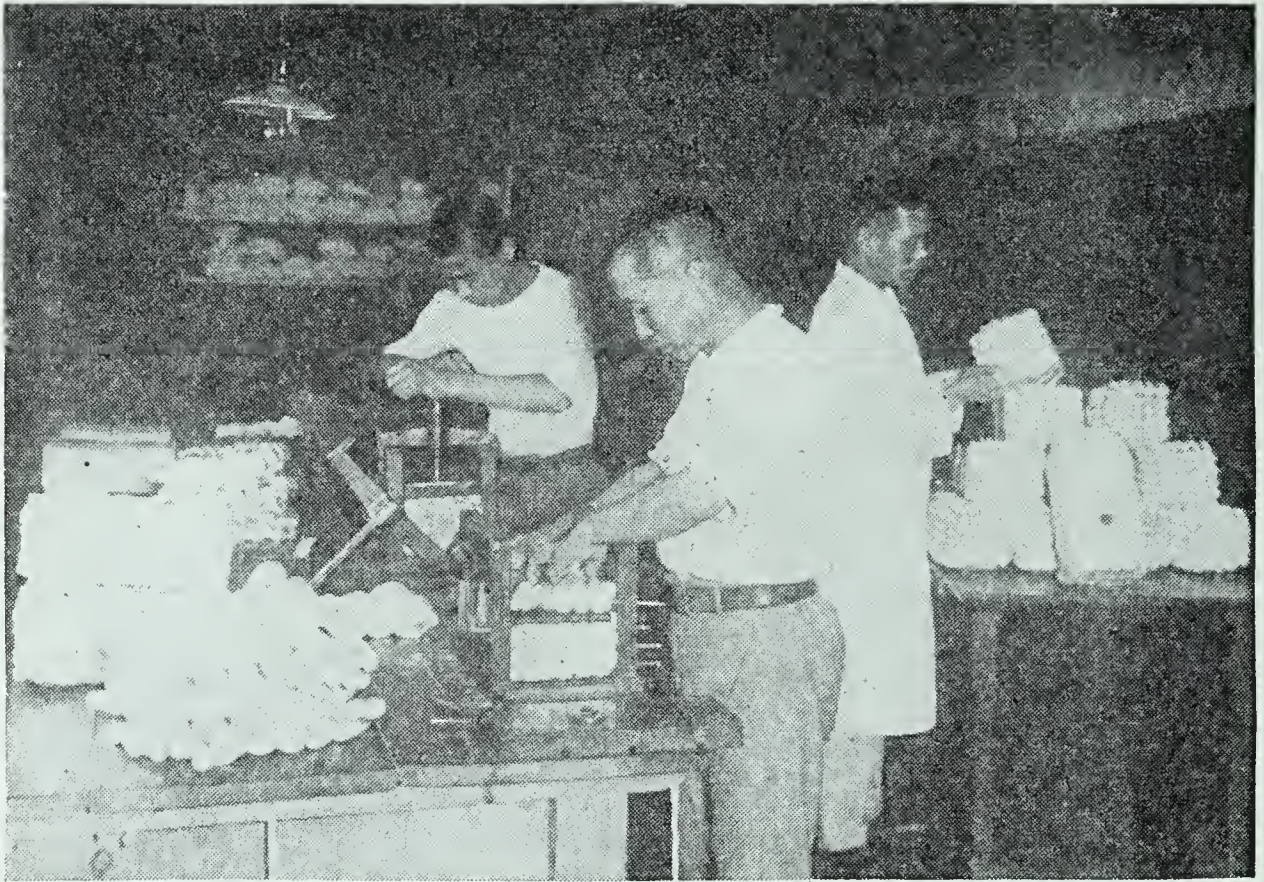
Reeling. The unwinding of the fibers from the cocoons and the winding of the combined strands onto reels is the second step in the preparation of the fiber for use. This process was a part of the silk culture as practiced by ancient Chinese many centuries ago. It has been suggested that silk cocoons were probably cut up and the fibers twisted into a strand before it was discovered that the fibers could be removed in a continuous length. The ancient method of reeling was, like all hand methods, slow and tedious. Several cocoons were placed in



A large filature employing many trained workers reeling silk for the export trade.

basins of hot water to soften the gum, and the coarse outside fibers were removed. (See page 242.) Since the fine double filament was too delicate to handle alone, several of these double strands from as many cocoons were joined and wound into a skein. The gum which held the strands of silk together in the cocoon was softened but not removed before reeling. The excess was removed by twisting the strands around each other and passing them through an eye of some kind. The gum hardened again and cemented together the fine fibers in the skein of raw silk. Great care was exercised by the reeler to prevent breaking the fine, weblike filaments and to keep the combined strand even in size throughout. Sometimes it was necessary to add extra fibers or use less to maintain the evenness. The skein of silk was originally wound onto a stick; later it was wound onto a reel that was first turned by hand, then by foot power.

A part of the reeling is still done in the homes or in small



Silk skeins being made into "books" by workmen. A book consists of thirty skeins of raw silk. Thirty books make a bale.

filatures maintaining only a few basins. This process has, however, gradually been taken over by large *filatures* maintaining five hundred or more, and sometimes a thousand, basins. (See page 245.) Practically all silk reeled for export trade is handled in these large establishments. Here the power used is generally steam, the water in the basins is maintained at an even temperature, and automatic beaters brush off the coarse outer fibers. However, the process is primarily a hand process. It requires from three to six months to train a girl to be a successful reeler.

The cocoons are boiled in hot water, plunged into cold water, and then soaked in hot water. As many as five strands, each containing the double filaments from several cocoons, may be reeled at one time. If a cocoon ceases to bob up and down in the basin, the reeler knows that a filament has broken. She adds a new end which is kept ready in her hand for such an emergency. More even strands of raw silk that have been more thoroughly cleaned and evenly twisted are

prepared by these highly trained girls and by advanced methods than was possible by the primitive methods.

Only about 16 per cent of the weight of the cocoon is silk fiber, about half of which can be reeled. These fibers vary in length from 300 to 1,000 yards. The outside of the cocoon is coarse, rough, and tangled and cannot be reeled, and the inside is too weak to be reeled. These parts are known as *frisons* and make up most of the waste of reeling.

The skeins of reeled silk together with the waste silk that cannot be reeled make up the raw silk of commerce. Thirty skeins of raw silk are packed in bundles called "books," which weigh from five to ten pounds each. (See illustrations on opposite page.) Each book is wrapped in thin paper. Thirty books make a bale. The bales are covered first with cotton sheeting, then with heavy paper, and finally with tea matting. These bales, weighing a little less than 150 pounds, are ready for shipment to all parts of the world. (See page 248.)

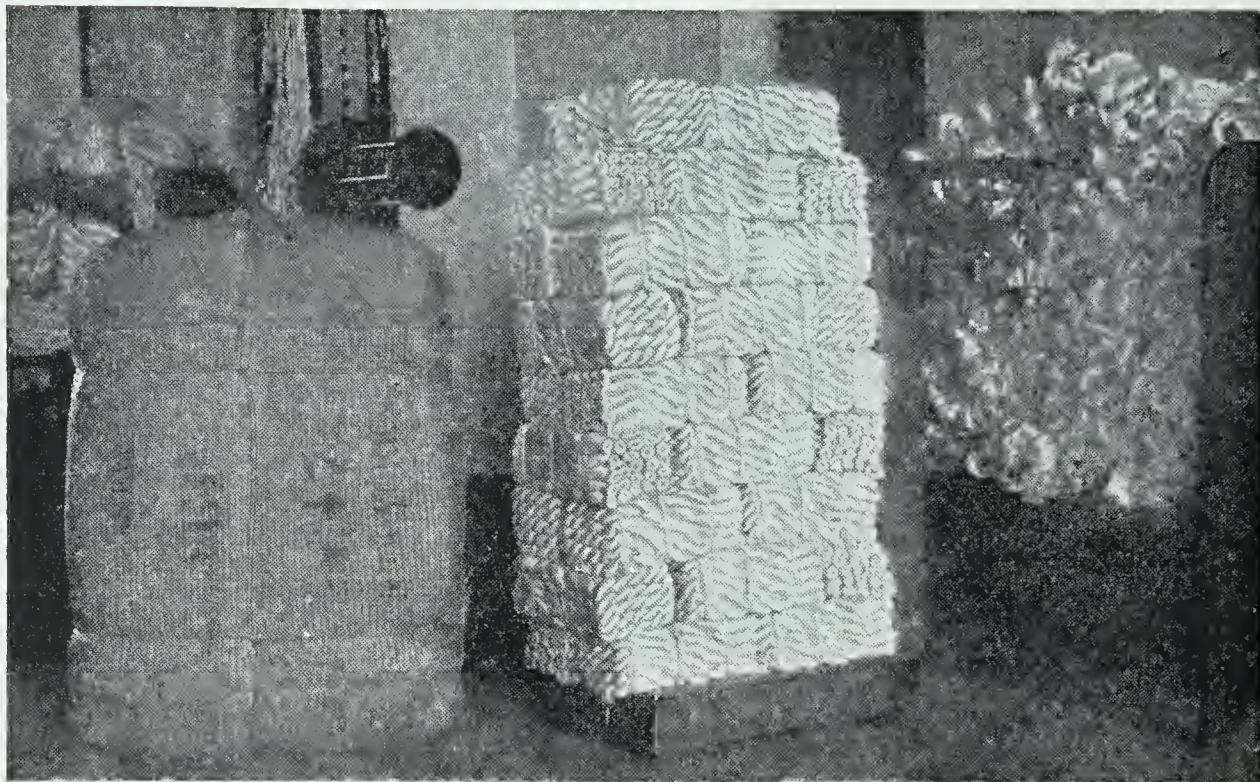
PROBLEM 2. HOW IS SILK YARN MANUFACTURED?

The process of yarn manufacture usually consists of the operations necessary to produce a continuous length or strand from short fibers. Reeled silk comes to the yarn manufacturer in the form of skeins of fibers which are already slightly twisted, continuous lengths of fine filaments.

Thrown silk. The production of yarn from reeled silk, known as throwing, consists of adding twist or of doubling and further twisting these strands into the desired size. Thrown or reeled silk yarns are classified as singles, tram, and organzine.

Singles are strands of raw silk consisting of from three to ten double filaments to which twist may or may not have been added. These yarns are used as either warp or filling or as both in the construction of woven fabrics, or they may be knitted into cloth.

Tram silk consists of two or more strands of singles slightly twisted together. These are generally used as filling and are often made from the imperfect fibers.



Courtesy The Corticelli Silk Co.

Bales, "books," and skeins of silk.

Organzine is formed by uniting two or more twisted singles by twisting them in the opposite direction. As this is used for the warp, it needs to be strong and is therefore generally made from the best, strongest fibers.

If the yarn is to be dyed, the gum or sericin must be removed. This makes it necessary first to double and twist the raw silk, because untwisted or only slightly twisted filaments would separate during the dyeing process.

In the throwing of silk the bales of raw silk are sorted, and skeins to be thrown without soaking are taken directly to the winding machine. Most skeins are opened, placed in bags, and soaked for several hours in a soap solution to soften the gum before they are thrown. Yarn manufacturers often tint the different grades of silk during the soaking process in order to distinguish grades more easily in future handling. After soaking and drying, the skeins of silk are stretched on reels and wound on bobbins. Excess sericin and irregularities in the silk are removed by passing the strand through a small slot or gauge.

Several types of silk thread or yarn are sold for hand work.

Silk thread, with which we are most familiar, is made by uniting and twisting two, four, or six strands of reeled silk. Embroidery silk is made by uniting several untwisted threads into one by a slight twisting. The size or count of reeled and thrown silk is determined by the denier system. A denier, which is a legal coin, weighs 0.05 gram. The size given is the weight in deniers of 450 meters of the reeled silk. Thus the denier is the weight in grams of 9,000 meters of thrown silk. A correction of 25 per cent is often made for the gum which has been removed in degumming. A more accurate method would be to give the size of the degummed silk, as it is impossible to determine the percentage of gum that has been removed.

The following data concerning the number of filaments in reeled silk were given out by the Silk Association of America:

Spring Crop	13/15 denier, 4 or 5 cocoons to a thread
	16/18 denier, 5 or 6 cocoons to a thread
	20/22 denier, 6 or 7 cocoons to a thread
Summer and	
Autumn Crop	13/15 denier, 5 or 6 cocoons to a thread
	16/18 denier, 6 or 7 cocoons to a thread
	20/22 denier, 7 or 8 cocoons to a thread

Each cocoon is built up of two filaments; therefore a 13/15 denier spring-crop thread contains 8 to 10 filaments, and so on. The number of filaments in thrown silk depends upon the crop and number of cocoons used. The individual silk fibers vary slightly as to size but are approximately 1 1/3 denier in weight. The comparative size of a silk yarn may be determined by multiplying the number of filaments by 1 1/3 deniers. Of course, the greater the number of filaments used, the coarser the yarn and the higher the denier count.

Another method of determining the count of silk yarn is to compare it with a yarn of known count. These last two methods are the ones employed to determine the size of yarn used in the construction of warp-knit goods from which it is impossible to ravel enough yarn to weigh.

Spun silk. Yarn is manufactured from waste silk by a process similar to that used in the manufacture of yarns from other short fibers. All silk that cannot be reeled is classed as waste silk. Cocoons that have been pierced by the moth, wild cocoons, and all imperfect cocoons, together with the frisons or waste from reeling, comprise the material that is made into spun silk. These fibers may be of the best quality but lacking the length necessary for reeling, as those taken from the more nearly perfect cocoons saved for the production of disease-free eggs, or they may be defective, as those taken from the imperfect cocoons.

The first process in the manufacture of spun yarn from waste silk is to remove the gum. To do this the material is usually boiled in a soap solution. The degummed silk is picked and shredded and cut into nine-inch lengths. It is then combed, passed through drawing frames, and finally spun into a yarn which is cleaned by gassing and is made into skeins by winding it onto a reel. These skeins of spun silk are used as warp or filling, or as both yarns in the construction of fabrics of good quality.

The shorter lengths of silk waste, material which cannot be utilized in spun silk yarns, have been made into continuous lengths by dissolving them and spinning the solution with apparatus similar to that used in the construction of rayon. The filament obtained in this way is said to compare favorably with the original filament spun by the silkworm.

PROBLEM 3. WHAT ARE THE MICROSCOPIC AND PHYSICAL CHARACTERISTICS OF SILK?

Physical characteristics. The value of silk as a textile fiber is indicated by the fact that it is more expensive than any other textile fiber. This cost is due to the expense in producing the fiber as well as to the special machinery and care necessary for its manufacture into fabrics. If silk did not possess properties not obtainable in other fibers it would not be used as a textile. Its characteristics of strength, fineness,

and length permit more cloth to be made from one pound of silk than from any other natural fiber. This, spoken of as covering power, adds to its value and reduces the comparative cost of the finished product. Silk is the only natural fiber which can be woven or knitted directly into a fabric in its raw state.

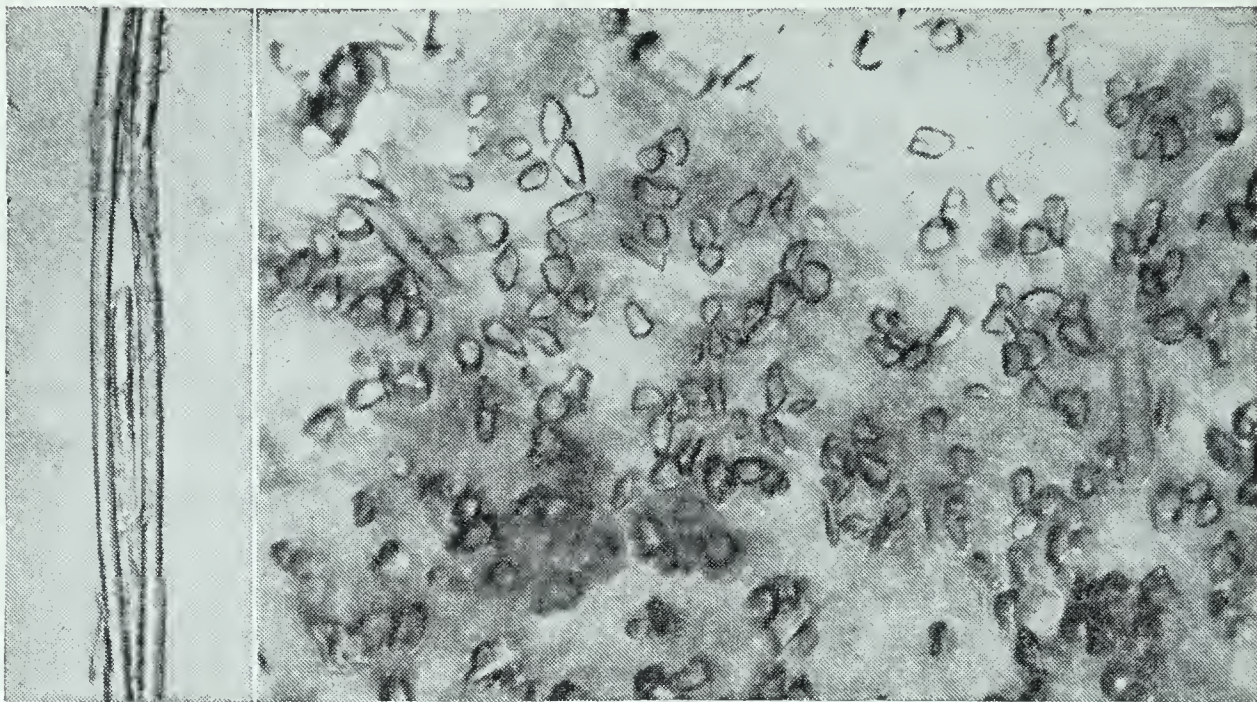
Part of the value of silk is the esthetic value due to its luxurious texture and soft, deep luster. This may be equaled by some kinds of synthetic fibers but not by any other natural fiber. The silk fiber is stronger than any other natural fiber, retains most of this strength when wet, possesses great elasticity and durability, and is by far the finest of the natural fibers. It also has the advantage of being the lightest in weight of all the fibers, having a density of 1.30 to 1.37 for raw silk, and density of 1.25 for boiled-off silk. Silk, then, is the longest, lightest weight, strongest for equal cross section, and finest of all the natural fibers.

Silk absorbs moisture from the atmosphere; like wool it is said to hold as much as 30 per cent of its weight without feeling wet. At the time of sale the amount of moisture in silk is determined in official laboratories, the regain permitted being 11 per cent. Excess moisture increases the weight and elasticity of silk but decreases its breaking strength.

Silk is a poor conductor of electricity, which permits the use of this fiber for insulating wires in electrical apparatus. Being a poor conductor, silk becomes electrified by friction in the manufacturing processes. The maintaining of standard conditions of 65 per cent relative humidity at 70° F. will lessen or overcome this difficulty. Oiling is also used to reduce static.

Scroop, that peculiar crackling sound which is emitted when silk is rubbed together or squeezed in the hand, may be said to be acquired rather than natural but is possessed to a greater degree by this fiber than by any other. This peculiar effect is obtained by working the fiber in a dilute acid bath and drying it without washing.

One of the properties of silk that makes it a practical fabric



Photomicrographs of longitudinal and cross sections of cultivated raw silk.

for garments is the ease with which it can be cleansed. The smooth surface and freedom from short fibers causes it to shed dust and give up dirt readily.

Microscopic characteristics. The silk fiber, as it is spun by the cultivated silkworm into a shell or cocoon to serve as a protection during the dormant stage, is the result of a natural life process but not the result of growth. The individual fiber may be considered to be without structure, although some authorities say it is capable of subdivision into many tiny fibrils. A microscopic examination of raw silk as it is reeled from the cocoon shows double filaments rodlike in appearance and more or less covered with lumps. The surface of the fiber has a striated or cracked appearance. This is the gum or sericin which holds the fibers together. Raw silk varies from cream to bright yellow in color and is comparatively harsh to the touch. Boiled-off or degummed silk is a single strand of fiber almost microscopic in size and white or nearly so. The cross section of this fiber is irregular, approaching an equilateral triangle in proportions. It appears cylindrical in longitudinal section without a central canal. (See illustration above.) The slight irregularities seen under high magnifica-



Photomicrographs of longitudinal and cross sections of wild silk. Note width of fiber as shown in cross section.

tion are characteristic of this fiber and are the result of its irregular secretion by the worm.

Wild silk differs from the cultivated fiber in microscopic appearance and in physical characteristics. (See illustration above.) The longitudinal section is broad and flat, and shows characteristic markings which run obliquely across the fiber, giving the appearance of shadows. The cross section approaches an isosceles triangle in proportions. Wild silk is coarser and less regular than cultivated silk and is more diffi-

cult to handle in the manufacturing and finishing processes. The gum is removed with difficulty.

Suggestion for the Laboratory

Study, under high power magnification, mounted specimens of longitudinal and cross sections of cultivated silk and wild silk.

PROBLEM 4. HOW DOES SILK REACT CHEMICALLY?

The two secretions from which the silkworm spins its cocoon, although both of animal origin and protein in nature, are chemically different. Approximately 66 per cent of raw silk is the fiber or fibroin, 22 per cent sericin, 11 per cent water, and 1 per cent oil and coloring matter.

In order to free the fibroin from its gluelike case of sericin and render it capable of acquiring dyestuffs and a satisfactory finish that will enhance the beauty and sheen of the silk, it is necessary to find a solvent for sericin. The removal of sericin, fats, and oils from the fibroin is termed degumming. This process has undergone certain changes but is usually accomplished by means of water, soap and an alkali.

Silk degummed with soap becomes weighted in the soap solution and this weight gives a superior body and elastic spring to the silk so treated, which it does not readily lose.

Silk, like wool, is a protein; therefore it yields amino acids upon hydrolysis, contains—CO—NH—groups, and is quite similar to wool in general chemical behavior.

Heat. Silk can be heated to a higher temperature than wool without disintegration. However, if white silk is held at 231° F. for fifteen minutes it becomes a pale yellow. For this reason silk garments must be dried carefully after laundering and should be pressed quickly with an iron that is not too hot. Above 330° F. silk disintegrates. Degummed, unweighted fibers burn in the air and produce an odor similar to that of burning wool, but not so disagreeable. Unweighted silk burns with a characteristic sparkle, leaving a black, crisp, easily crushable ash. The burned portion is usually semicircular in form. Heavily weighted silk fibers burn with difficulty

and leave a relatively large amount of residue. Heavily weighted silk fabrics retain their shape when burned. In the burning of both weighted and unweighted silks, it will be noted that the material ceases to burn when it is removed from the flame, hence it is not considered a fire hazard.

Silk is attacked by the ultraviolet rays of the sun. Chemists formerly attributed this weakening to metallic weighting, but it has been demonstrated that although silk that has been weighted is more quickly injured than unweighted silk, whether raw, degummed, or weighted, silk is more sensitive to light than any of the other fibers. After six hours' exposure to an ultraviolet lamp, raw silk lost 50 per cent of its original strength; degummed silk showed a similar decrease after two to two and one-half hours; and weighted silk after one and one-half to two hours, depending upon the amount and kind of weighting present.¹

Water. Water does not permanently affect the silk fiber. It decreases about 20 per cent in strength when wet, but regains the original strength upon drying. The fiber swells, but does not dissolve, when steeped in warm water.

Acids. Silk resists the action of concentrated acids such as sulfuric, nitric, and hydrochloric less than wool, dissolving readily in these reagents. A dilute solution of nitric acid produces a bright yellow color on silk similar to that formed with wool. Silk is affected by hydrochloric acid in any form. This fact permits the use of this acid in separating wool from silk in analysis. If silk is treated with concentrated sulfuric acid for only a few minutes, then rinsed and neutralized, it shrinks and has less luster but shows little loss in strength. This method is used in creping.

Dilute acids are readily absorbed by silk. They increase the luster and develop a scroop. Tannic acid is used as a mordant and in weighting.

Alkalies. Silk is less sensitive to alkalies than is wool. It dissolves in hot concentrated solutions and also in the hot dilute solutions, but more slowly than wool. The fiber is unharmed

¹George H. Johnson, *Textile Fabrics*, p. 313. Harper and Bros., New York, 1927.

by borax, ammonium carbonate, and soap solutions. However, a mild soap is recommended for laundering silk.

Bleaches. When entirely degummed, the silk fiber needs little bleaching. If the fiber is not white, or in case some of the gum is retained, bleaching is done with the same reagents as are used for wool, namely, sulfuric acid or sodium peroxide. Such bleaching compounds as Javelle water make silk yellow and tender. Javelle water contains sodium hypochlorite, which tends to decompose and liberate chlorine. Chlorine is a good oxidizing agent and attacks stains and colors, and in the case of silk attacks the fiber also.

Dyestuffs. Dyestuffs are absorbed by silk more readily and at a lower temperature than by any other natural fiber. Since it is a protein, this fiber possesses both acid and basic properties and therefore reacts easily with basic or acid dyes.

Perspiration. Silk garments often break under the armpits or across the shoulders before the remainder of the garment is worn out, owing to the effect of perspiration. Deodorants which contain aluminum chloride also cause a tendering of the fabric. Because perspiration becomes alkaline and tenders silk, hosiery made of this fiber should be laundered as soon as removed.

Ammoniacal solutions. Ammoniacal solutions of copper and nickel salts are good solvents for silk. The nickel compound is sometimes used to separate this fiber from cotton.

Weighting. Silk fabrics, if woven in the gum, are stiff, harsh, yellow, and unsightly. When this gum is removed preparatory to the finishing and dyeing processes, from one-fifth to one-fourth of the weight of the silk is lost.

Silk manufacturers sometimes use certain metallic salts in processing silk. Stannic chloride is used for weighting unless the material is to be dyed black. In that case iron salt and logwood are used. An amount of tin weighting not exceeding 10 per cent seems to have no injurious effect on silk fabrics and may even tend to increase the breaking strength. However, an excessive amount of tin weighting is most injurious to the fiber, although it has little effect upon the luster. (See page 257.) From 8 to 10 per cent tin salt is absorbed from a cold so-

lution of stannic chloride. When the material is rinsed in water, the tin salt hydrolyzes and stannic chloride is deposited on the fiber. Before the silk can take up a fresh charge of weighting the tin is fixed by treating it with a solution of sodium phosphate or silicate. After washing, the process is repeated until the desired amount of weighting has been added.

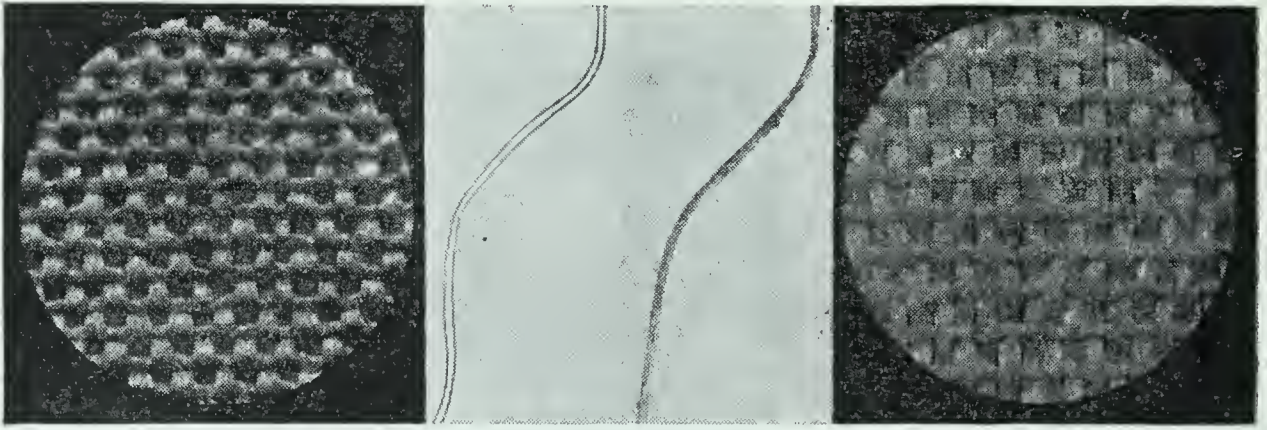
Black silk is often dyed and weighted in the same process, logwood and an iron salt being used. If the weighting has been properly done, slightly more than one-fourth of the weight lost may be added without no-

ticeable injury to the fabric. If you examine most taffeta and similar materials you will see that they are stiff and heavy, though not having many ends and picks. This means that a large percentage of weighting has been added. If metal weighting has been used it will be permanent. Soluble finishing, which will be removed by the first cleaning, may have been used.



Courtesy National Association Institute of Dyeing and Cleaning, Inc.

This is an actual photograph made of a piece of weighted silk that has been subjected to the burning test. Note the charred edges of the burned portion which stand out stiff, yet flaky.



Photomicrographs by Hatch and Reutlinger, *Textile World*, Vol. 84 (1934), p. 1824

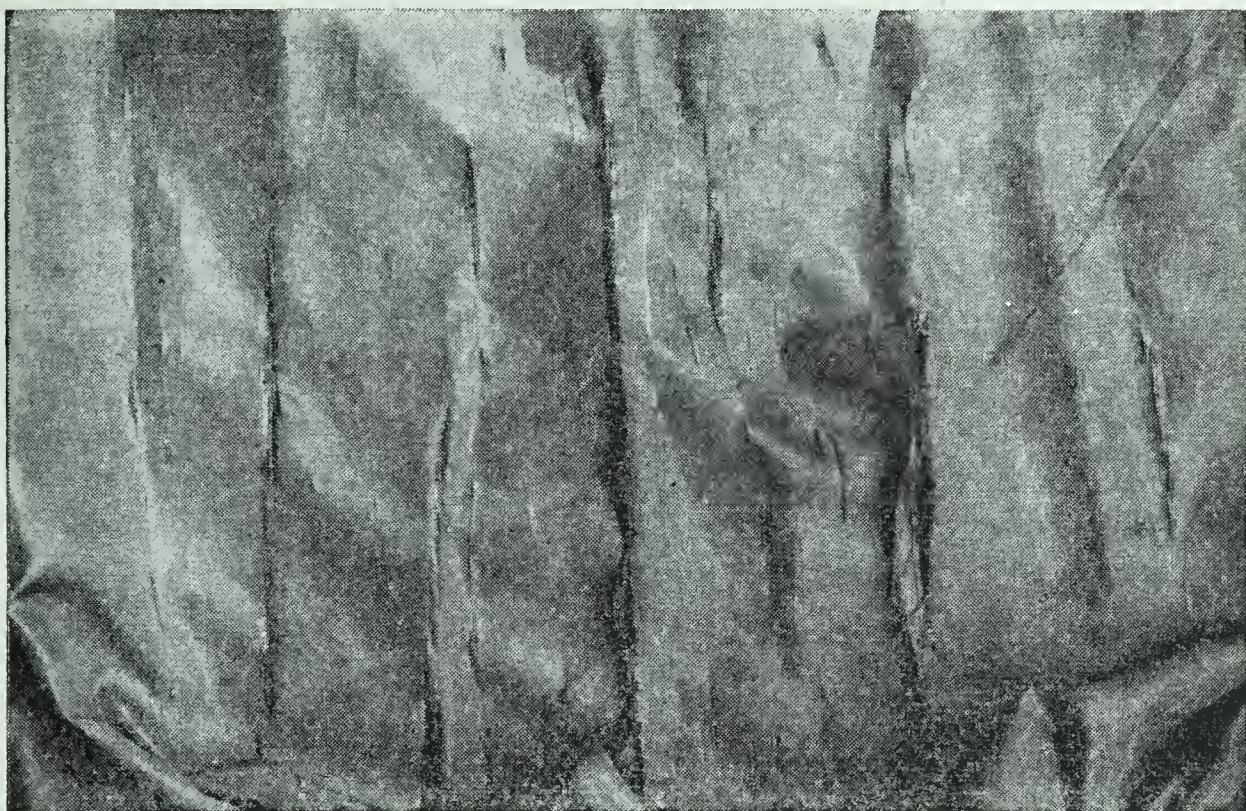
Micrograph taken of same area of pure dye and weighted flat crepe. Note the lower number of yarns in both warp and filling of the weighted fabric; also the crystals of weighting clinging to the fiber and making it dull.

The amount of silk weighting that is “safe”—that is, which will not injure the fabric—is an open question. At one time a large portion of the silk on the market was so heavily weighted as to give little service. (See page 259.) The realization that the excessive weighting of silk was injuring the trade caused several leaders in the Silk Association to set up maximum standards for silk weighting.

Much research work has been done to determine the effect of weighting on the washability and durability of silk. As a result of these investigations many firms are producing material without weighting which they are labeling “pure dye” or “non-weighted silks.”

A label of “Pure Dye” indicates that not more than 10 per cent of any substance has been added during finishing. According to the F.T.C. Trade Practice Rules, special finishes that enhance the properties of the cloth are permitted. Silk fabrics carrying no label as to content may contain not only weighting but other fibers in varying percentages. (See the illustrations above.)

Today comparatively few fabrics that contain metal weighting are offered for sale. This is because labeling laws require that such fabrics must carry information on this point. This ruling has not resulted in a lack of taffeta and other stiff silks but rather in the development of permanent finishes



Courtesy National Association Institute of Dyeing and Cleaning, Inc.

A section of a weighted silk curtain which disintegrated through the action of moisture and acid-forming gases in the atmosphere.

that give to the cloth the desired body but are in no way injurious to its service qualities. Some of the new finishes render the fabric crease-resistant also, and others make them water-repellent.

Tussah silk, a variety of wild silk, is more difficult to degum than cultivated silk because the fiber contains more mineral matter and the gum is harsher and more resistant to the action of soap. This silk is colored by the tannin contained in the oak leaves on which the worms feed. The sericin is difficult to remove completely, for it penetrates into the fiber proper. The stripped silk is brown, the color pigments not being confined to the sericin as in the case of cultivated silk. Tussah is difficult to bleach, owing to the impurities in the fiber and its inactivity toward chemicals, and because all sericin must first be removed before bleaching can be achieved. The peroxide method is generally used for bleaching this type of silk. Tussah silk is usually found in pongees and shantung where the color and unevenness of the fiber are utilized as a fashion note.

PROBLEM 5. HOW DOES THE GEOGRAPHIC SOURCE INFLUENCE THE QUALITY OF THE SILK FIBER?

Countries producing and using silk. Practically every civilized country has at some time undertaken the cultivation of silkworms and the production of silk. It has been proved that the climate of California is well suited to the production of silk, that the worms are exceptionally free from disease, and that the fiber is of excellent quality.

In 1943 the California legislature authorized the appointment of a committee to study the possibilities of silk production in that state. At the present time California is devoting considerable attention to this subject. They report that machinery has been invented in the United States which is adequate for the tending of the silkworms and the reeling of the cocoons.

The following are given as some of the strong points in favor of California as an ideal place for the development of silk culture.¹

1. To produce silk at a low cost there must be special climate free from frost, free from too much rain, and free from thunder and lightning.

2. American machinery has been invented to replace the cheap Asiatic labor.

3. California can produce three crops annually, while Japan can produce only one crop a year.

4. California can derive from \$1,000 to \$12,000 an acre from the production of silk.

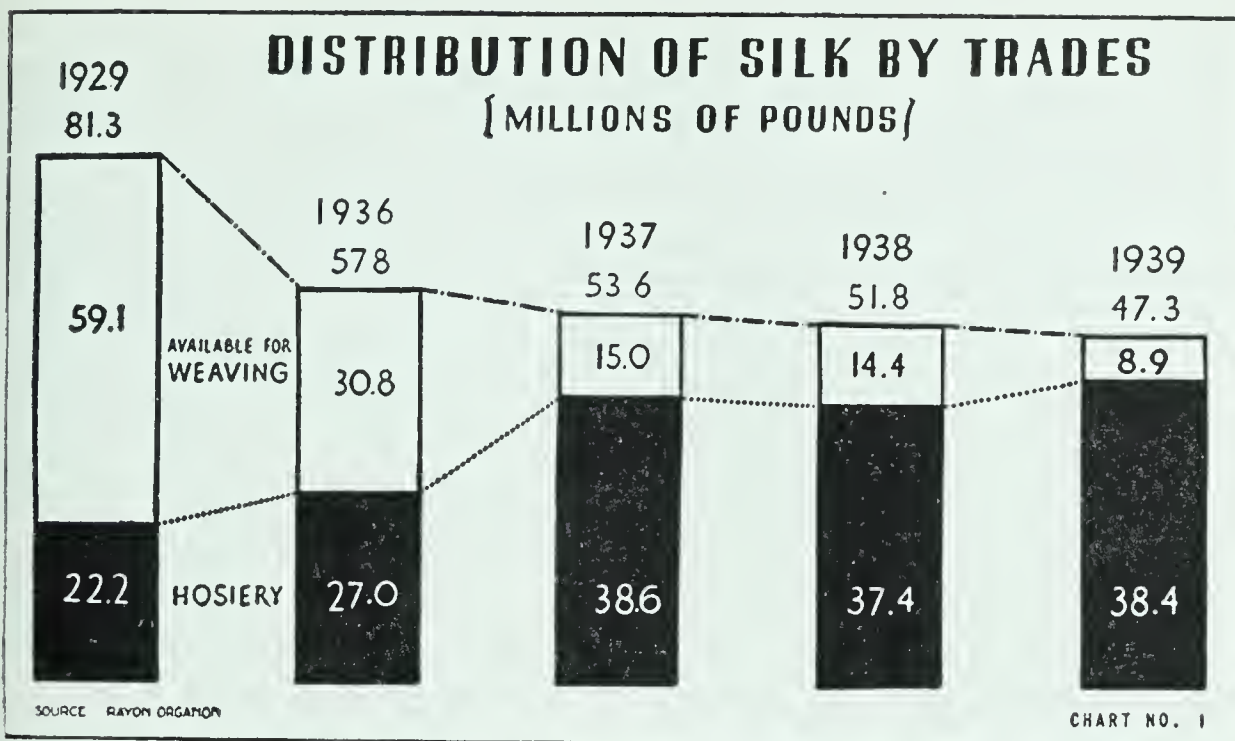
5. The quality of silk produced in California is 60 per cent better than the silk which is produced in Japan.

6. No special skill is required to produce silk, a person 75 years of age or a child 10 years of age can do the work.

7. A mulberry leaf picking machine has been invented which will reduce the cost to the farmers and make a good substitute for the cheap labor of Japan.

8. We also have a reeling machine which does the work that was done by manual labor in Japan. So now we can go into the silk industry on mass production.

¹ *California Digest*, Vol. 3, No. 4, May, 1945.



Courtesy *Rayon Textile Monthly*

A comparison of the amount of silk used in weaving with that used for hosiery, from 1929 to 1939.

We can understand the unlimited possibility we have in this state when we realize that the United States has been importing \$300,000,000 of raw silk annually from Japan. All this silk and more can be produced in California. When that raw silk is manufactured into a finished product it has a cash value of \$1,200,000,000.

Reports of experimental or small quantity production of silk in England indicate that there is nothing to prevent the rearing of silkworms in that country. The silk produced is reported to be comparable to that which comes from other countries. There is evidence of recent development of silk culture in several South American countries. The production of raw silk has been subsidized by the government of Brazil since 1923. Sericulture is seen by some as a possible new industry for many countries in the postwar age.

Japan, China, Italy, and France have been the chief sources of raw silk. Data given in the table on page 263 show the amount and value of silk imported into the United States from 1924 to 1934.

The greater portion of the silk used in the United States

has come from Japan. This fiber is of excellent quality but is not so clear a white as that produced in China. In Japan special efforts have been made to meet the demands of the American manufacturers for strong, clean fibers. The control of disease and the production of disease-free eggs for distribution was under the supervision of the Japanese Government. Silk was produced on a large scale under scientifically controlled conditions, but the number of families rearing silkworms in their homes was over ten million, it will be remembered. Less than one-third of the silk produced in Japan was for home consumption. Probably 90 per cent of the silk exported by Japan was sent to the United States.

The following information was given in a service bulletin published by the United States Testing Company, Inc.

JAPAN'S POSTWAR RAW SILK INDUSTRY

The Japanese are starting to rebuild their raw silk industry. The cocoon farmers are confronted with a choice between further curtailing their mulberry cultivation in order to produce more food crops or to replant their land with mulberry to feed silk worms and have a cash-producing crop. It is probable that most farmers are balancing the prospects of financial return but there have been reports of farmer groups who have stated that if they could be assured there would be a sufficient supply of food imported by the sale of the raw silk abroad they would expand their cocoon production. Between 1940 and 1945 the mulberry acreage declined 60%, the families growing cocoons 45%, and the cocoon production 75%.

Operating silk filatures appear to have decreased even more than the cocoon growers. During the same period the number of filatures declined 91%, the number of reeling machines 85%, and the production in exportable bales 85%. Even domestic consumption decreased 62%. The innovation in the industry is the production in 1945, for domestic use, of 8,267,000 lbs. of spun silk, showing the utilization of the excess of cocoon production over filature capacity.

Raw silk stocks as of December 31, 1945, total 85,000 bales. Estimated production for the 1946 calendar year is 120,000 bales. Due to a lack of experienced reeling girls, it is believed that only about 70% of the stocks and estimated production will be of exportable grades and quality. It is planned to export 130,000 bales

during 1946 which will leave approximately 75,000 bales for domestic manufacture in Japan. It is believed that 80% of the silk shipped from Japan will be consigned to the United States.

The cocoon stock reported as available is sufficient to reel about 170,000 bales indicating an excess of cocoon supply over filature capacity sufficient to produce about 50,000 bales. Some of the surplus cocoons will be carried over to 1947, and some will be processed into spun silk for domestic consumption.

According to estimates made by the Japanese Government Raw Silk Bureau in the early part of January, 1946, there are 21,800 basins (figured as multiple-thread basins) operating at 70% capacity and producing 5,500 bales per month. The total production for the silk year 1945 (ending May 31, 1946) is forecast as 74,898 bales.

There are 3,655 stored basins which will be installed during January to March, 1946, and it is estimated that additional new basins will be installed by the end of the calendar year, December, 1946, to bring the total of basins to 42,944.

Between January, 1946, and May, 1947, it is estimated that the Japanese filatures will reel about 184,916 bales of which 70% or 129,440 bales should be suitable for export.

The addition of the current stock pile of exportable silk totaling 9,500 bales indicates a total of 188,940 bales available for export in the next 18 months.

Between the years 1924 and 1929 Japan sold the United States a yearly average of 61,000,000 pounds of raw silk at an average price of \$5.59 per pound. In 1934 the year's import of silk from Japan was only 57,500,000 pounds, at an average of \$1.30 a pound.

The volume and value of raw silk more recently exported to the United States are as follows: ¹

DATE	VOLUME	VALUE
1938.....	393,426 bales	297,973,146 yen
1939.....	331,524	437,611,019
1940—Jan.....	9,639	20,160,004
Feb.....	11,425	20,630,004
Mar.....	13,496	23,977,858
Apr.....	12,419	20,445,018

Note: One bale = 60 kilograms.

¹ K. Oiwa, Secretary, The Central Raw Silk Association of Japan, Tokyo.

RAW SILK DATA ¹

YEAR	PRODUCTION	EXPORTS	DOM. CONSUMPTION
1940.....	717,000	313,000	365,000
1941.....	536,000	20,400	462,000
1942.....	473,000	11,000	436,000
1943.....	265,000	7,780	255,000
1944.....	142,000	0	140,000
1945.....	100,000	0	
1946.....	111,000	0	

Note: Listed in bales.

It would require a pound of raw silk to make two dozen pairs of hose or three inexpensive silk dresses. It is estimated that at least 80 per cent of all the silk that has come into the United States has been used in the manufacture of hose. We all remember the sudden replacement of silk with nylon for this purpose.

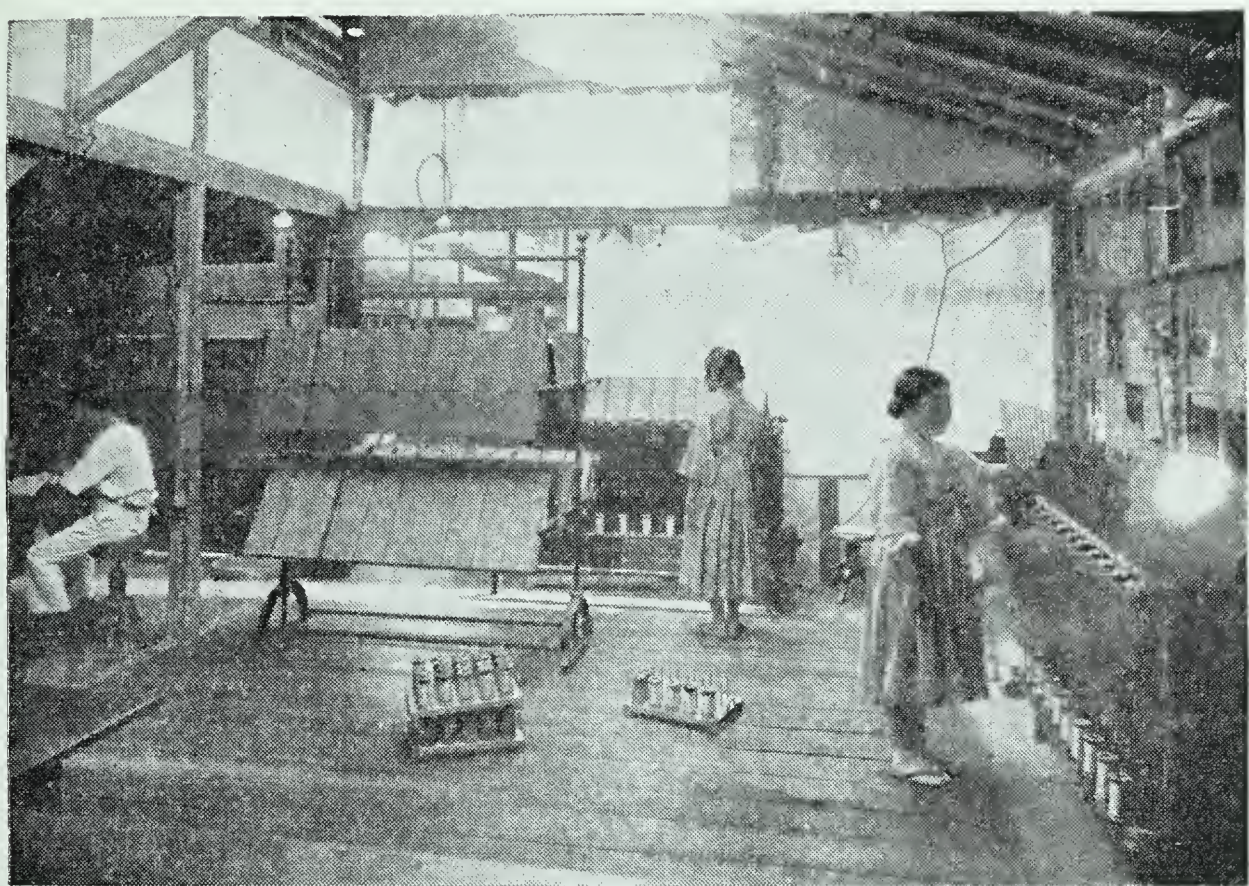
Much progress has been made during recent years toward improving the grade of the silk produced in China. This was accomplished even during the war through the development of a new strain of silkworms that produce a better grade, more uniform fiber. Six large breeding farms were operated, and from these six farms the farmers were supplied on contract.

Vast destruction due to the war, transportation, inflation, and exchange difficulties have combined to prevent any export of Chinese silk for some time. American and Chinese business men believe it will require from three to five years for China to rebuild her silk industry.

The Italian silk is of high quality. The raw silk may be yellow in color because of the color of the sericin. When this is boiled off, a white fiber remains. The greater part of this silk is consumed in the United States. The principal raw-silk markets of the world are Yokohama, Shanghai, Canton, and New York City. San Francisco and Seattle are important receiving ports.

Determining quality. A committee of the Silk Association of America set up specifications resulting from a series of

¹ *Rayon Organon*, January, 1946, p. 11.



Applying physical tests to silk for the determination of quality.

CHARACTERISTICS OF SILK FIBERS

Microscopic	
Appearance	Longitudinal—double transparent filaments Cross-section—triangular
Length	300–1,000 yds.
Diameter	9–11 microns
Color	Light to dark cream
Luster	High
Strength	4.0–15.5 grams per denier, 5.25 grams per fiber
Elasticity	High (15–20%)
Heat conductor	Poor
Effect of heat	Scorches easily
Water absorbency	30% of weight
Standard regain	11%
Effect of moisture	Reduces strength and increases elasticity
Effect of sunlight	Very sensitive
Attack by mildew	Yes
Attack by moth	No
Attack by carpet beetles . . .	Yes
Effect of acids	Less resistant than wool
Effect of alkalies	More resistant than wool

physical tests, which furnish a basis for intelligent grading of raw silks. (See page 265.) Officially approved conditioning houses grade the silk according to quality and prepare it for sale according to grade and on a conditioned basis. Eleven per cent regain is permitted for raw silk and 9.25 per cent for boiled-off silk.

REFERENCES FOR ADDITIONAL STUDY

- De Garis, Frederic. *We Japanese*, H. S. K. Yamaguchi, 1937.
The Story of Raw Silk, The Central Raw Silk Assoc. of Japan, 1939.
 J. M. Matthews, and H. R. Mauersberger, *Textile Fibers*, John Wiley and Sons, July, 1947.

Unit Four

COTTON AND OTHER SEED HAIRS

COTTON is king," the old slogan that indicated the supremacy of cotton exports in American trade, may still be applied to the relation of cotton to the fibers, for it is the most universally used of all fibers. There is, in fact, practically no cloth or article made of textile fibers for which cotton cannot be used. Although the position of cotton is gradually changing it will be some time before its supremacy in amount consumed is replaced by any other fiber. In order to compete with synthetic fibers in price, it has been estimated it will be necessary to produce cotton that can be sold for less than ten cents a pound. This cannot be done by methods commonly practiced in the United States at the present time, but these methods may change. (See page 277.) The mechanization of the production and harvesting of cotton was interrupted by the war but efficient apparatus for the handling of cotton on a completely mechanized basis has been produced and it is only a matter of time until this method will entirely replace the old expensive hand processes. The old practice of producing cotton on small farms of wornout land must also yield to the production of diversified crops on much of the land and the raising of cotton only in large areas of the better land. It is no longer profitable to raise cotton on land that yields less than one bale per acre. Livestock and timber are replacing cotton as crops in many areas in the south.

Experience and experimentation during the recent war demonstrated the advancement possible by more expert selection and breeding of cotton for particular uses. Spinning tests have proved that predetermined specifications can be

attained through the selection of specific varieties and blends which make for greater economy.

The physical structure of the cotton fiber is being carefully studied. Attention is being given not only to the breeding and growing program but also the spinning needs. The developments that are occurring in cotton agriculture and processing, when added to the progress being made in yarn and fabric finishes, will permit the production of a variety of cotton fabrics never duplicated in the history of the textile industry.

The range of usefulness of cotton goods has been greatly increased. One illustration is the wide use of cotton clothing for cold climates, which resulted from extensive research carried on during the war. Cotton fabrics that are light weight and warmer than fur, noninflammable and waterproof cotton, and cotton fabrics that will not shrink nor fade will aid this fiber in competing with synthetic fibers of the future.

Until recently cotton was our greatest single export and approximately 70 per cent of all the raw fibers produced in the world are cotton. (See table on page 166.) This fiber makes up the bulk of the clothing and household fabrics and has a wide range of use in the industries. In the United States approximately one-third of the cotton goes into clothing, one-third into industry, and one-third into articles for household use. The importance of cotton is shown by the fact that in 1940 cotton was produced on approximately one-fourth of the six million farms in the United States.

The production of cotton and the manufacture of cotton fabrics date back to a period before recorded history. India may be considered the birthplace of this fiber and records show that five centuries before the Christian era it was already in use there. The production and manufacture of cotton slowly spread through Persia and Egypt into Europe and northern Africa. The first use made of cotton in England was in the manufacture of candle wicks. It was imported for this purpose toward the end of the thirteenth century. For many years cotton fibers, which are the shortest of our textile fibers, could not be spun into yarns that were strong enough to serve



Courtesy Bessie Walker Callaway, La Grange, Georgia

Cotton picker, as he walks down a row at a time.

as warp. It was therefore mixed with linen and wool long before it was manufactured into an all-cotton cloth. Because the production and manufacture of wool was well established as a national industry in England, the introduction of raw cotton or cotton cloth was opposed. However, the few fine cotton fabrics scattered throughout Europe by crusaders and medieval traders created a desire for this material that has been stated by some to have been one of the causes of the Industrial Revolution, which followed in a later period.

The cotton plant was found in Mexico and the United States by the early explorers and so may be considered indigenous to this country. The greater portion of cotton produced in the United States today is known as upland cotton and was developed from these native types. For many years cotton was produced only in small quantities in the United States. All of the textile industries were carried on in the home and until near the end of the eighteenth century a large part of the work was done by hand. The fibers are so tightly fastened to the seeds that they are difficult to remove by hand, and one person could seed only from one to two pounds of cotton in a day. For this reason but a small quantity could be handled by a household. The years between 1760 and 1800 were filled with events important to the development of the cotton industry. During this period textile machinery was invented in England: the spinning jenny by Hargreaves (1764), the spinning frame by Arkwright (1769), the spinning mule by Crompton (1779), and the power loom by Cartwright (1785). The application of steam power to spinning and weaving machinery made quantity production possible and influenced the introduction of the factory system. England prohibited the export of any cotton-manufacturing machinery and so the first machinery in the United States is said to have been constructed from memory by Samuel Slater, who had worked in the English mills, and the first factory was erected in 1791 from plans made by him.

The invention of the cotton gin in 1793 by Eli Whitney was probably the most important event in the development of cotton industry in the United States. (See page 271.)



Courtesy The Bettmann Archive

The first cotton gin used on a southern plantation.

Whitney's gin made possible the seeding of several hundred pounds of short-staple cotton in a day in contrast to the one or two pounds that could be seeded by hand. Since the United States is peculiarly adapted to the growth of this type of cotton, this invention was of great importance, and cotton is now one of our major crops.

In 1943 cotton was grown on 21,652,000 acres, and the average yield of lint cotton was 253.5 pounds per acre, a total yield of 11,427,000 bales with a farm value of \$1,129,985,000.¹ Sixteen states producing cotton, listed in order of the amount produced in 1943, are Texas, Mississippi, Arkansas, Alabama, Georgia, Louisiana, South Carolina, North Carolina, Tennessee, Oklahoma, California, Missouri, Arizona, New Mexico, Virginia, and Florida.

There were 1,700 bales of sea-island cotton, grown principally in Georgia and Florida, with small amounts in Ala-

¹ Agricultural Statistics, U.S.D.A. 1944, p. 71.

bama, Mississippi, Arkansas, Louisiana, and Texas; and 28,000 bales of American-Egyptian, grown principally in Arizona.

PROBLEM 1. HOW IS THE COTTON FIBER PRODUCED AND PREPARED FOR SHIPMENT?

The hard labor long associated with the production of cotton is fast being replaced by machinery even in the United States. This is necessary to permit the cotton grown here to compete in price with that produced in other countries, and to prevent the replacement of it by synthetic fibers.

Growing and harvesting. A warm climate with from six to seven months of summer is necessary for the growth and harvesting of the cotton plant. A light loamy soil, plenty of rainfall, and a gradual rise in temperature insure the best development of the fiber. This limits the production of cotton in the United States to the southern states. Here conditions differ so widely that generalizations are difficult. However, in all countries the cotton is planted as early as possible in order to assure time for its development before the first frost. The seeds are usually sown by machine (See page 273.), in a continuous stream in rows three to four feet apart. When the plants are a few inches high, the rows must be thinned by cutting out the undesirable plants. This is often done with a hand hoe and is known as chopping. (See page 274.) Several types of machines have been developed for the chopping of cotton and some of these can successfully compete with hand methods. This is one of the slow hand processes connected with the growing of cotton which is being replaced by machine methods. However, men, women, and children are still required in large numbers for this type of hard work.

Upland cotton grows to a height of about four feet and blooms two to three months after planting. The blossoms last but a day, and when they fall off, the boll begins to develop. These seed pods or bolls contain the seeds to which the fibers are attached. When the cotton is ripe the bolls burst, exposing a soft fluffy mass of fiber. (See page 275.) The cotton must be

picked soon after the bolls open to prevent the fibers from becoming discolored and dirty from exposure to the sun and weather. The bolls on the lower part of the plant and under side of the branches develop before the others. Because of this uneven development it is necessary to go over a field several times in order to pick the cotton as it matures, adding to the amount of labor and cost of production. In normal times cotton pickers are paid from three-fourths to one and one-half cents a pound and a good worker can pick by hand as much or more than 300 pounds of cotton a day. The fiber is picked and dropped into a sack which the worker carries suspended from his shoulders. (See page 269.) The work is heavy, but because of the price paid there is a great exodus of men, women, and children from the cities to the cotton fields during picking time.

Heavy rains at this time result in great injury to the crop. Some cotton is beaten out of the pods and much of it becomes discolored and dirty. Early frost is another cause of damage to the crop. Bolls opened by frost will contain discolored fibers. In many localities cotton continues to mature until December or until the first killing frost. Each field is gone over two or more times, depending upon the quantity produced and the value of the crop. When the selling price is low and perhaps an early frost catches a large portion of unopened bolls, the last cotton may be gathered by raking over the field with machinery. This produces a type known as



Courtesy Bessie Wasker Callaway, La Grange, Georgia

Planting the cotton seed.

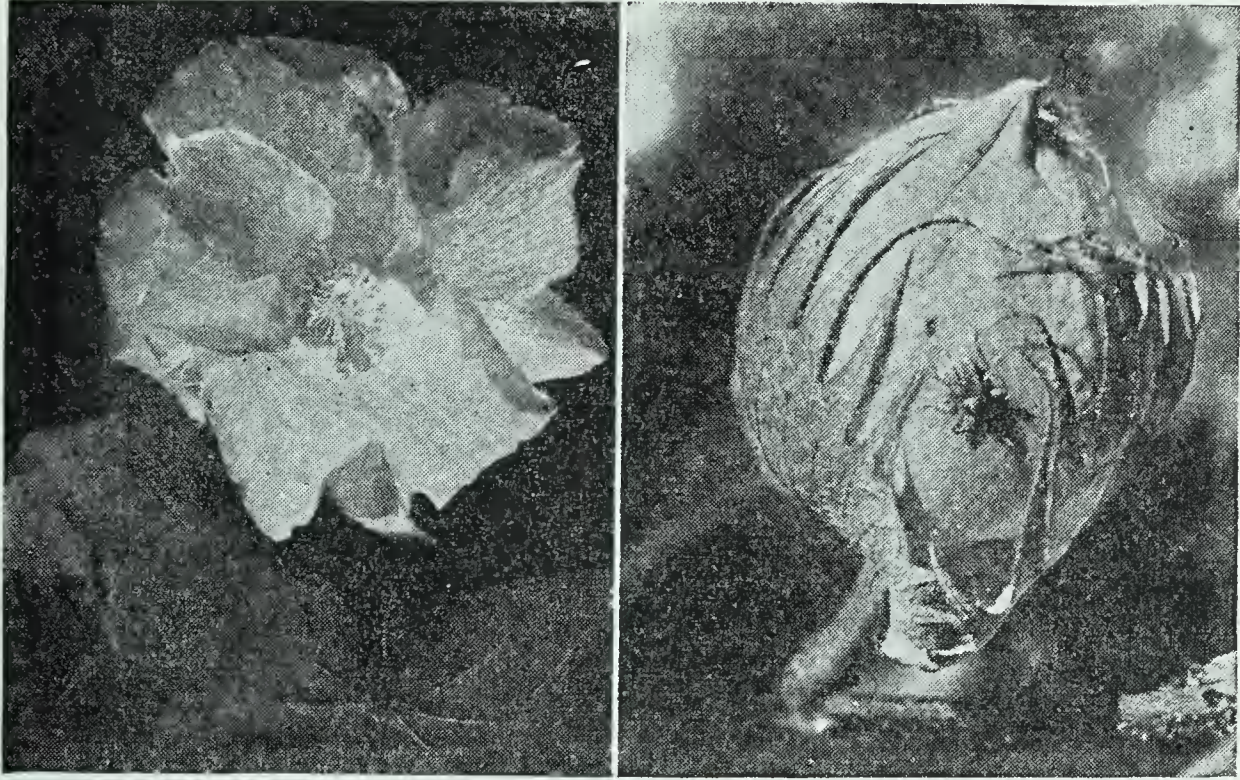


Courtesy Bessie Walker Callaway, La Grange, Georgia

Thinning the cotton by hand chopping.

bollies, which contains large quantities of foreign matter and dirt. Bollies are cleaned and ginned by a special process and yield usable fiber. Cotton as it is taken from the field contains the seed and is known as seed cotton.

Mechanical pickers of various types have appeared on the market from time to time, the first patent being granted in the United States almost 100 years ago. Many types have appeared and patents have been granted for machines operating



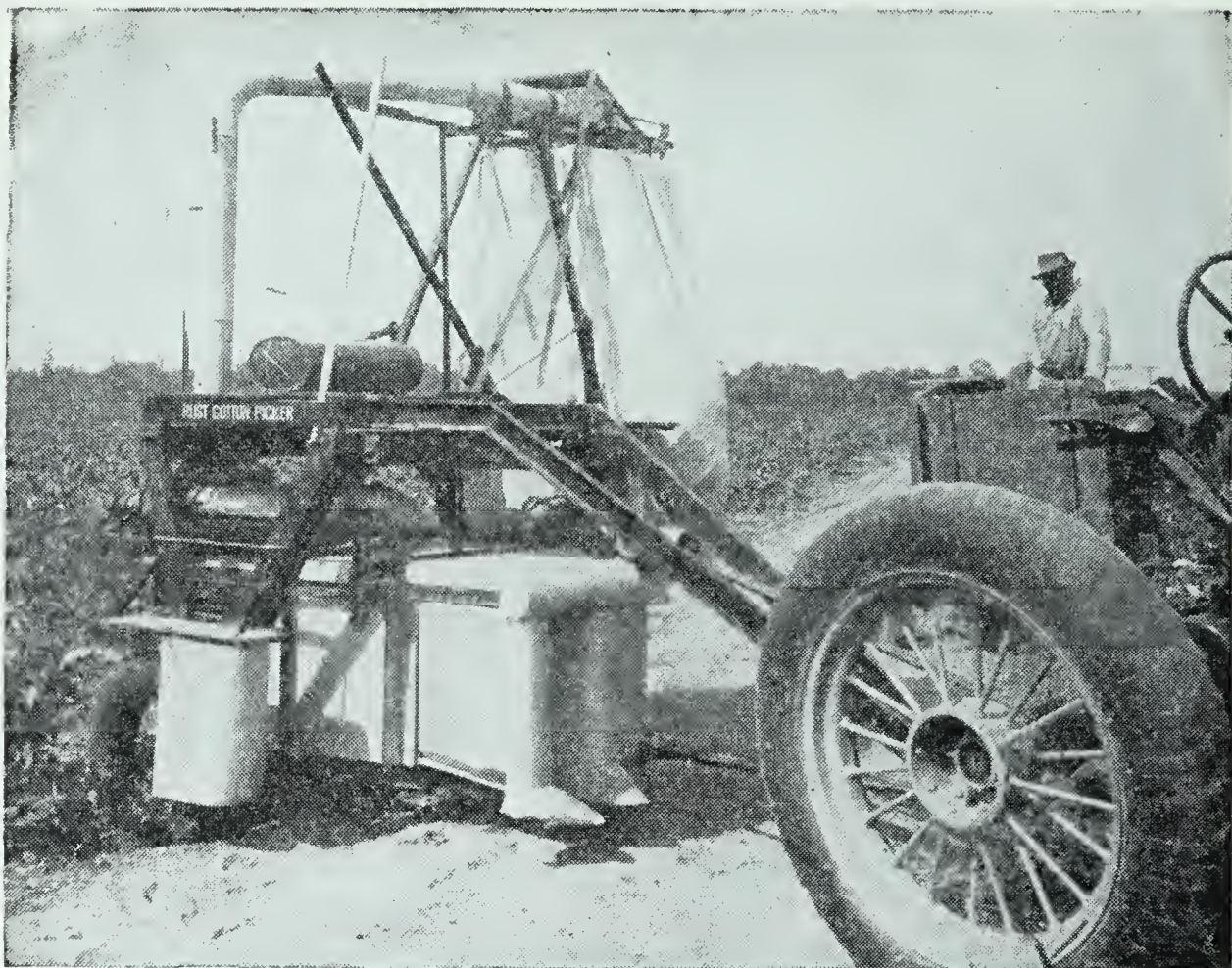
Courtesy Bessie Walker Callaway, La Grange, Georgia



Top left, flower. Top right, boll pierced by the boll weevil. (This boll will not develop.) Bottom, perfect boll fully opened.

on such principles as the thresher, pneumatic blast, electro-matic and stripper.

Only a few machines have been efficient in operation, the most successful being based on the principle of rotating spindles. These spindles are either moistened or barbed and when coming in contact with the open boll, twist the fibers from them. Some types of cotton lend themselves to machinery picking. Such varieties as can be successfully picked by machinery are being developed. Because one mechanical picker



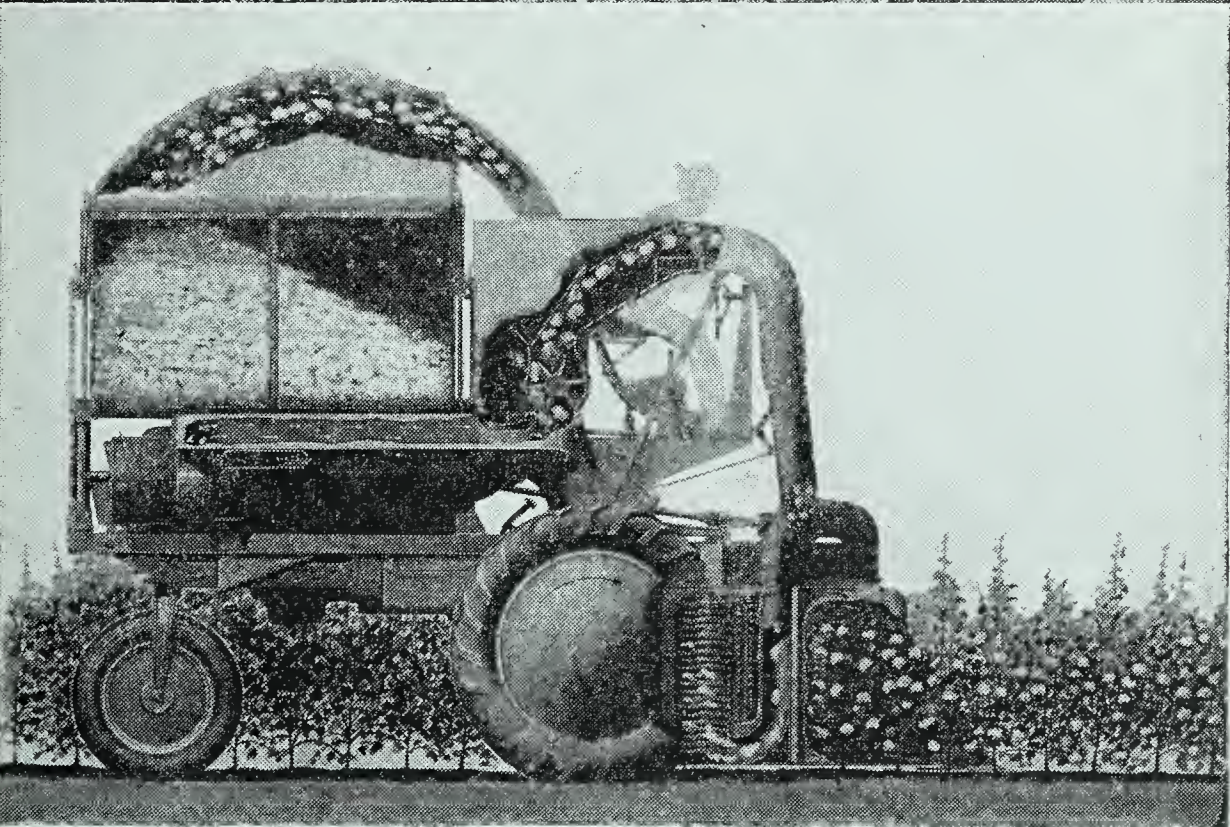
Courtesy Bureau of Agricultural Chemistry and Engineering, U. S. D. A.

Rust cotton picker. Note the two bags ready to receive the cotton.

can harvest many acres of cotton in a day, the cotton can be picked as soon as it matures, thus avoiding deterioration.

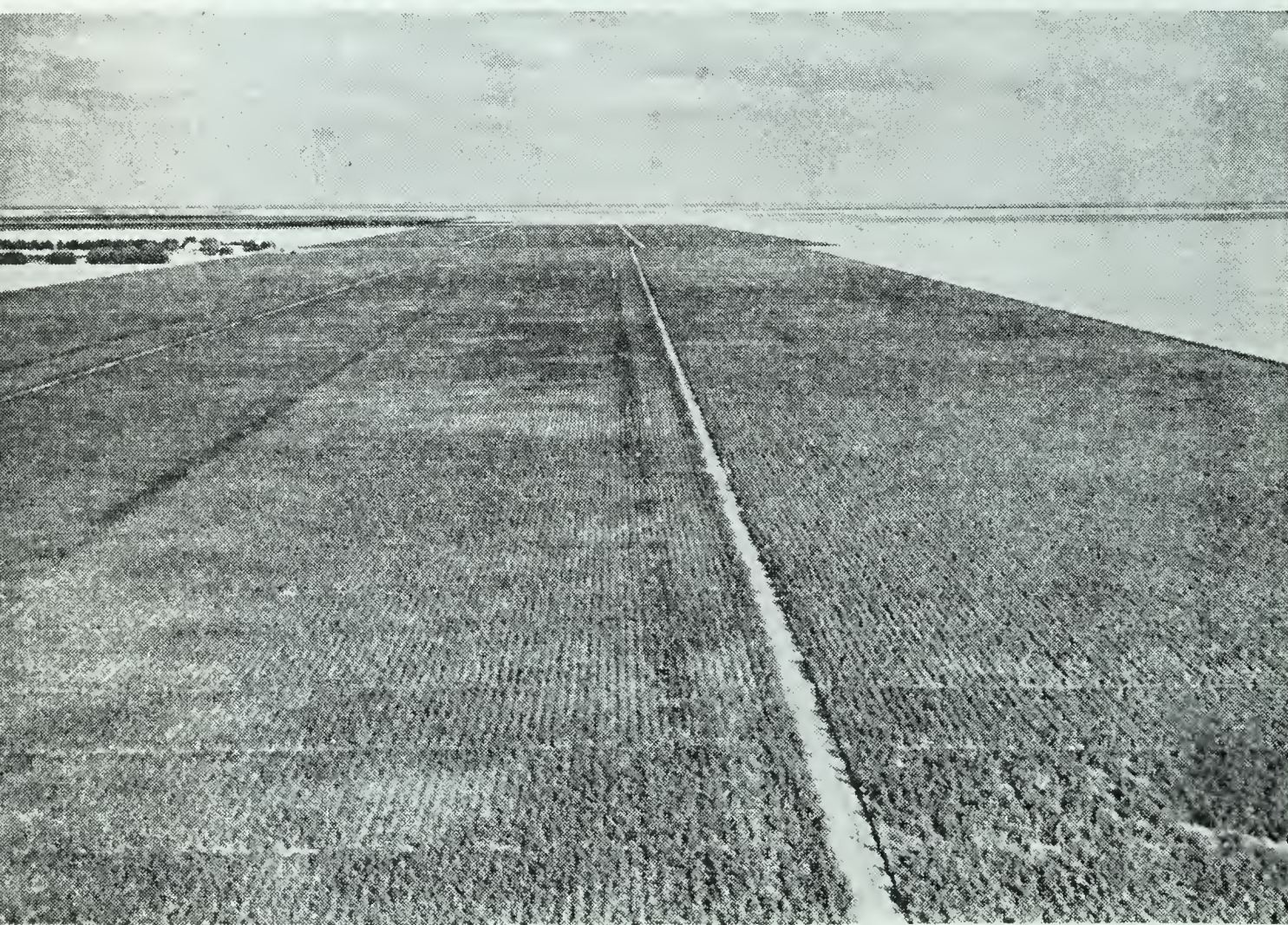
The average worker can pick by hand about 15 pounds of seed cotton per hour throughout the harvest season. Therefore, a machine harvesting 1500 pounds of cotton in two hours and 20 minutes would do the work of from 40 to 50 average workers. This would be done with a saving of from three to five cents a pound.

The larger amount of waste in machine-picked cotton as compared to hand-picked fibers reduces the grade. One method of overcoming this is to defoliate the field. The defoliating powder may be applied by airplane or tractor when the bolls are mature. The leaves dry up and fall off within six days after treatment. It has been reported that where this method has been used the bolls open more evenly, so that it is not necessary to go over the field more than once, there is



Courtesy International Harvester Co.

Top, International Harvester Company machine in action; and bottom, a cross section of machine showing the method of operation.



Courtesy *Life* magazine

Top, cotton field being sprayed from airplane. Bottom, a cotton field in full leaf.



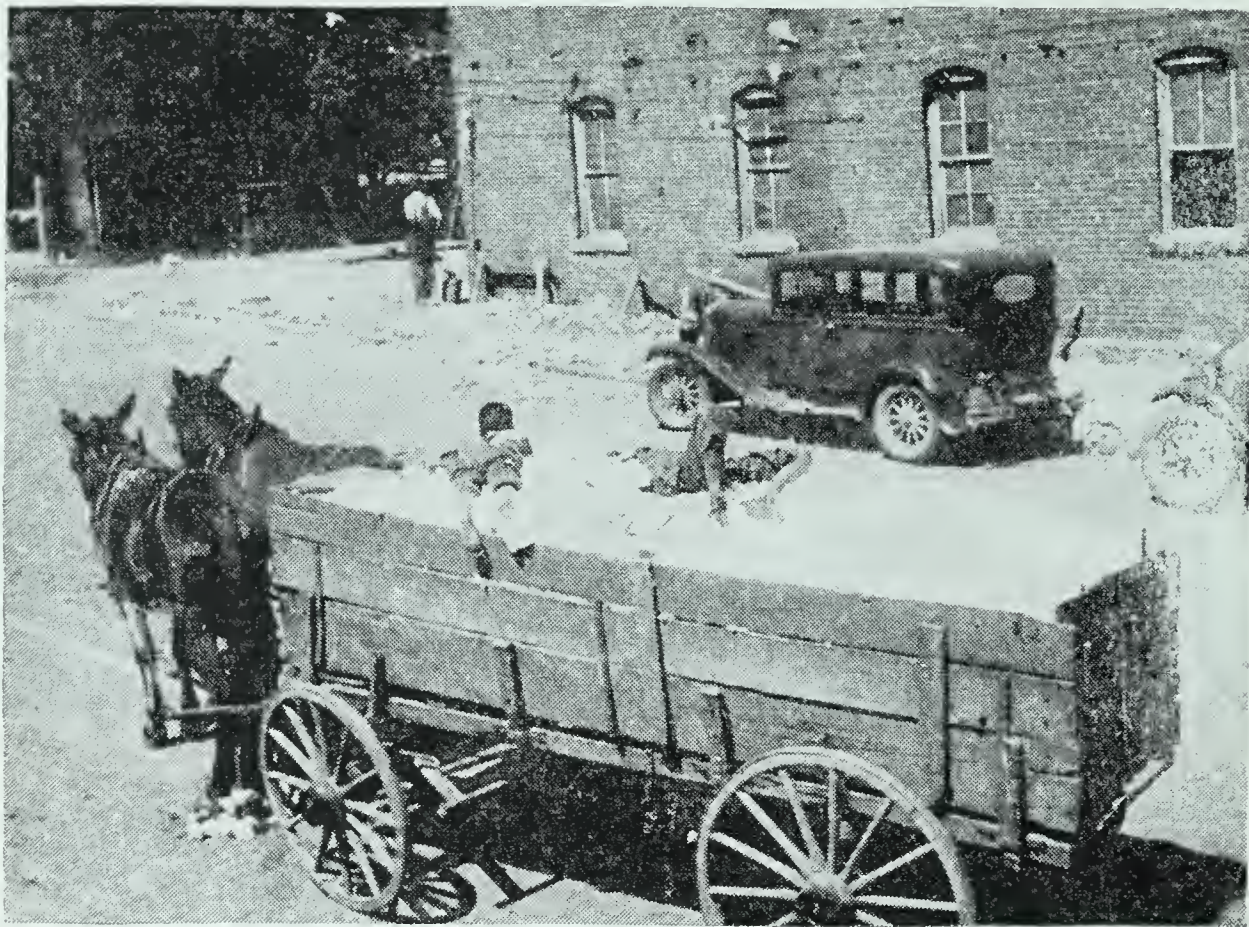
Courtesy *Life* magazine

The cotton field after defoliating.

less staining due to leaf or stem, and the fibers are exceptionally free from waste. (See the illustration above.)

In some areas mechanization has reduced the hours of labor required to produce one bale of cotton 80 per cent. The 160 man-hours required by inefficient hand methods have been cut to 28 man-hours for mechanized equipment. On the high plains or irrigated areas where all bolls open at the same time the stripper, by a raking action, takes all the bolls at once. This method has been used for some time to gather the last scattered bolls from a field. Its application to the harvesting of the entire crop, when feasible, reduces the man-hours even more.

Ginning and baling. The production of cotton is complete when it has been picked and is ready to go to the gin, but it is not in a salable form at this time. The seeds must be removed and the fiber made into a package or bale before it is sold. Seed cotton consists of approximately two-thirds seeds, one-third fiber, and a small amount of foreign matter such as leaf and dirt. At one time a cotton gin was a part of the equipment on each plantation. Today the gins are located in what is known as the wagon market, farmers' market, primary mar-



Courtesy Bessie Walker Callaway, La Grange, Georgia

Waiting at the gin.

ket, or local market. (See page 280.) The market must contain a gin, scales, and a place where buyer and seller may meet. These facilities are usually privately owned, and a fee is charged for services. In localities where cotton is raised on a comparatively small scale the farmer keeps two wagons and as soon as one is filled it is taken directly to the gin. The cost of ginning and baling includes the cost of bagging and ties. The cost of this service, although changing greatly from year to year, has varied less than the cost of harvesting during the same period as shown by the figures in the chart on page 281.

To this expense must be added the value of the farmer's time and, in some instances, injury caused by careless ginning. Twelve to fifteen minutes are required for ginning and baling 1,500 pounds of seed cotton, but in rush times the farmer may be required to wait many hours for his turn.

The average cotton bale weighs approximately 500 pounds. The farmer brings the cotton to the gin in lots varying from

AVERAGE FARM PRICES OF COTTON, AVERAGE GINNING RATES, AND
RELATIVE PRICES AND RATES, SEASONS 1928-29 TO 1935-36 ¹

SEASON	AVERAGE FARM PRICE PER POUND ¹	AVERAGE RATE PER 500-POUND BALE FOR GINNING AND WRAPPING ²	RELATIVE PERCENTAGE OF 1928-29	
			Farm Price of Cotton per Pound	Rate per 500- Pound Bale for Ginning and Wrapping
	<i>Cents</i>	<i>Dollars</i>	<i>Per Cent</i>	<i>Per Cent</i>
1928-29	17.99	5.96	100.0	100.0
1929-30	16.79	5.72	93.3	96.0
1930-31	9.46	5.08	52.6	85.2
1931-32	5.66	4.12	31.5	69.1
1932-33	6.52	4.25	36.2	71.3
1933-34'	10.17	4.80	56.5	80.5
1934-35	12.36	5.04	68.7	84.6
1935-36	11.10	5.04	61.7	84.6

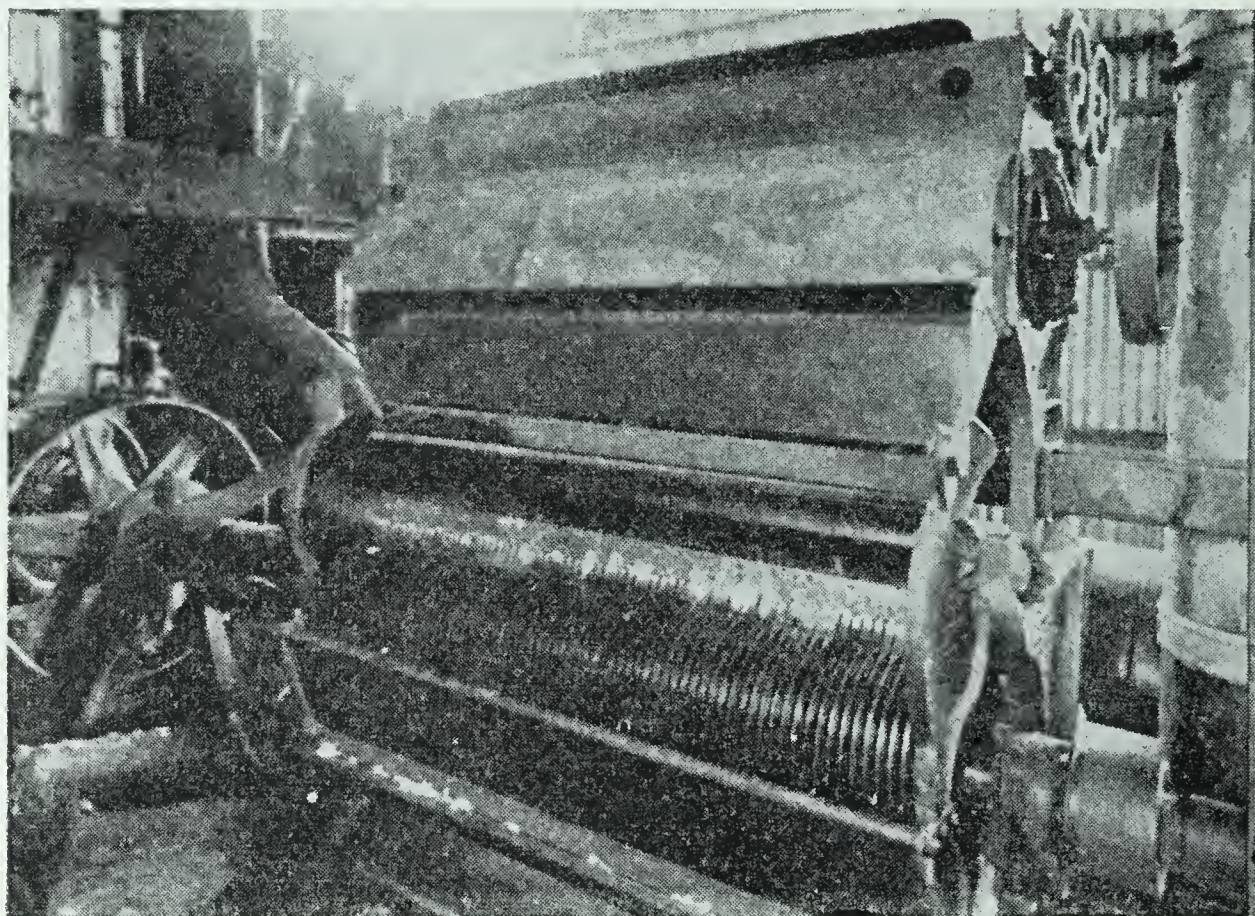
¹ Annual average for the United States. *Agricultural Statistics*, U. S. Department of Agriculture, 1936, Table 98, p. 76.

² Annual average for the United States. Compiled from data obtained from cotton gins.

1,300 to 1,600 pounds of seed cotton. The wagon is driven under a spout through which the cotton is drawn by means of suction. In some cases the cotton is stored in an upper room and fed down as needed. In most instances, however, the cotton is seeded, the lint baled, and the bale and seeds returned directly to the farmer. These bales of cotton fibers, known as lint, are the raw cotton of commerce.

The original Whitney gin consisted of a number of wire hooks or teeth so arranged that they caught the cotton fibers and drew them through a grate, allowing the seeds to fall to the ground. The principle of Whitney's gin is retained in the modern gin. Here the hooks are replaced by circular saws which project through a slotted plate. (See page 282.) Each gin can seed from 40 to 50 bales of cotton a day. Two men can take the cotton from the wagon and operate six or more gins at one time. This type has the advantage of speed but tends to cut and tear the fiber. The gin removes the seeds and a large

¹ J. W. Wright and W. B. Lanham, *Rates for Ginning and Wrapping American Cotton, and Related Data, Seasons 1928-29 to 1935-36*, p. 4, U. S. Department of Agriculture, Bureau of Agricultural Economics. 1937.



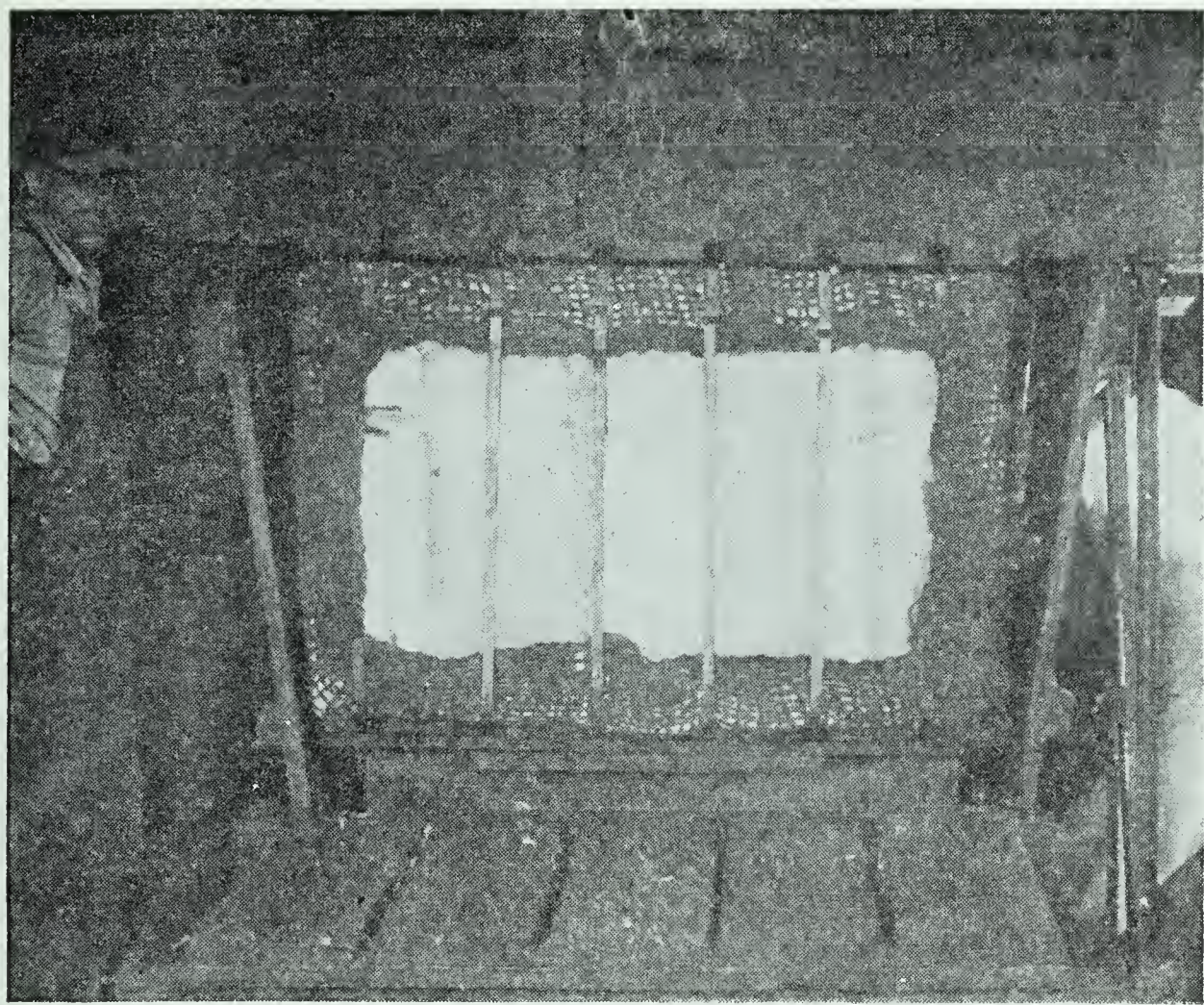
Courtesy bureau of Agricultural Economics, U. S. D. A.

Cotton gin removes the fibers from the seeds.

part of the dirt and other foreign matter and presses the lint into a bat ready for baling.

Improvement in ginning machines makes possible the successful handling of machine-picked cotton, even though it may not be so carefully selected as is that picked by hand. A gin that can handle cotton in the boll is another type that is being developed and will permit raking the field to obtain the last scattered bolls. Ginning and baling are separate processes, although the lint cotton is pressed into a bale immediately after the seeds have been removed. The bale is wrapped with jute bagging and bound with steel bands.

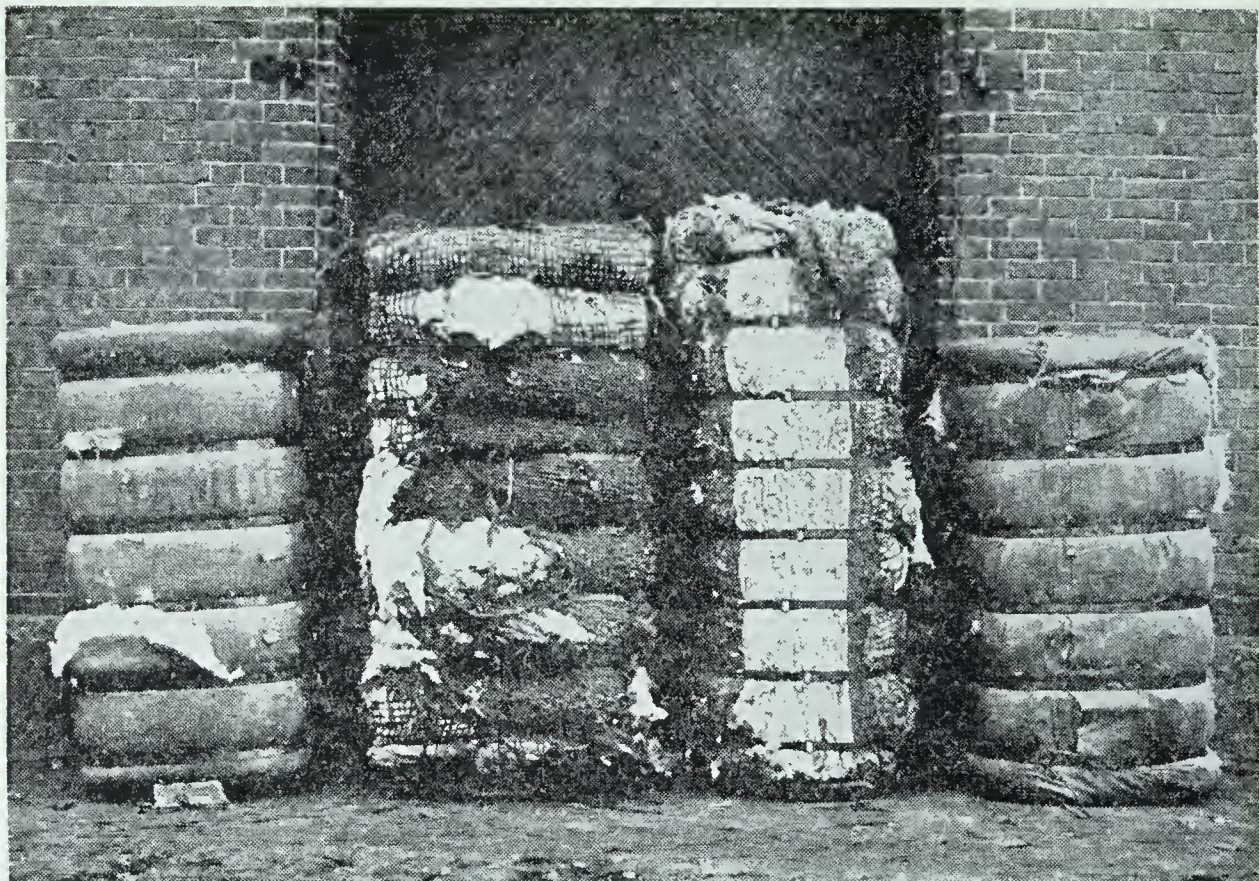
There are three types of bales: the square or plantation, the gin-compressed, and the round bale. (See page 284.) The standard size of the square bale is 54 by 27 by 45 inches. This bale weighs approximately 500 pounds, is clumsy and difficult to handle, and seldom has a covering sufficient to protect the cotton from dirt and exposure to the weather. The packaging



Courtesy Georgia Agricultural Experiment Station

Baling ginned cotton.

and marketing practices in the United States are being studied, and suggestions have been made for improvement. Experiments are being made with a new system of sampling during ginning which would eliminate the practice of slashing the covering after the bale leaves the gin. If this method were adopted it would prevent the loss due to the exposure of the cotton and improve the appearance of the bale. If trading were done on a net weight basis, suggested improvements in bagging and tying materials might more easily be adopted. The gin-compressed bale weighs the same as the square plantation bale but is compressed to half the space and is often used when the cotton is to be shipped. All square bales must be compressed before they are accepted for foreign shipment by water. The round bale is the most satisfactory. It weighs 250 pounds and is completely covered with a closely woven



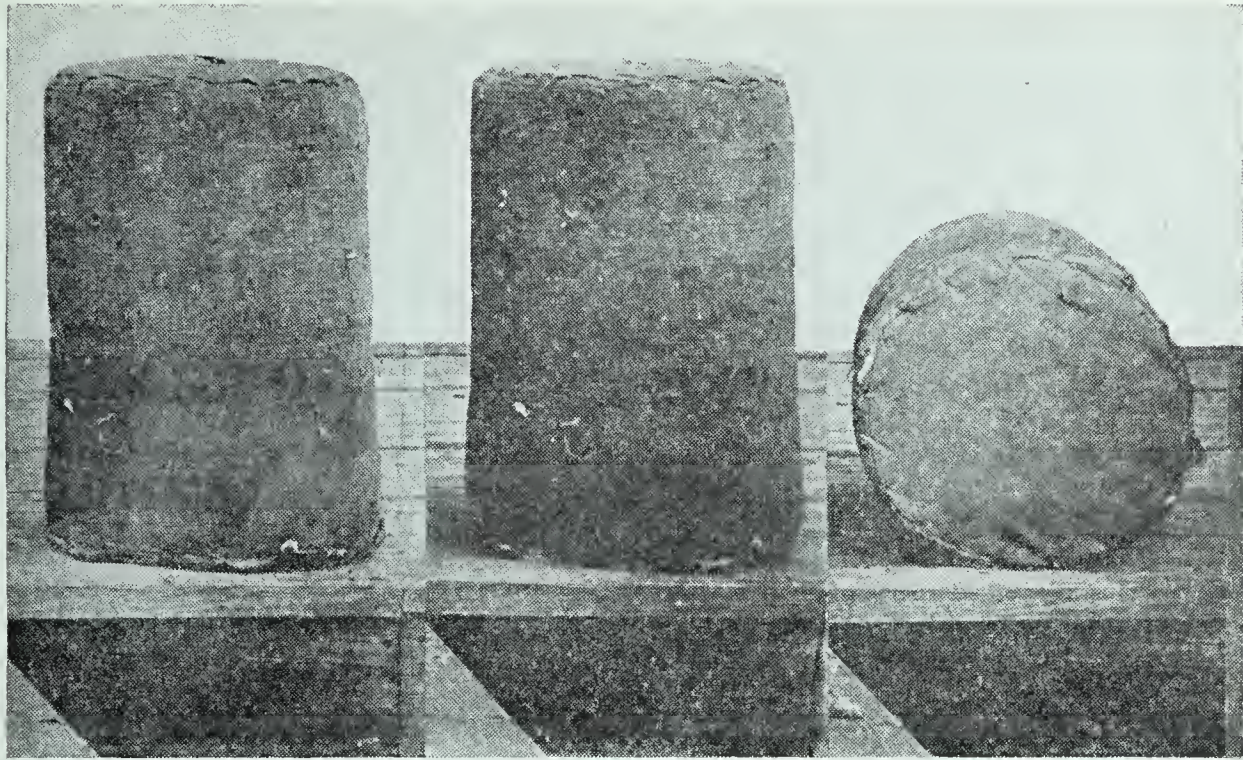
Courtesy Bureau of Agricultural Economics, U. S. D. A.

Comparison of gin-compressed and plantation bales. Note sample holes in gin-compressed bales.

bagging. These bales take up the least possible space, can be moved without hooks, and are easily handled in the factory. This type of bale is highly recommended.

The two types of cotton fiber, long and short staple, have entirely different kinds of seeds, necessitating different methods of ginning. The saw gins which handle the upland variety of cotton remove the longer fibers but leave the seeds covered with a short fuzz. A second ginning process is required to remove the short fibers or linters which amount to about 10 per cent of their weight. *Linters*, which may be considered a by-product of the cotton industry, are one source of raw material for the production of rayon. These short cotton fibers are used also in the manufacture of guncotton, cotton batting, stuffing material, and paper.

Sea Island cotton and other long-staple varieties have smooth, sleek seeds that can be handled by the roller gin. This type of gin was first used in India and remains today prac-



Courtesy Bureau of Agricultural Economics, U. S. D. A.

Side and end view of round bales, advocated because of complete protection afforded, and the convenience of size in handling.

tically the same as the original. In it, rollers covered with tough walrus leather hold the fibers, while the seeds are pushed off. The roller gin handles only about two bales (1,000 pounds) of cotton a day, but does not tear or cut the long fibers.

Cotton seeds furnish several commercial products. The cottonseed crop in the United States averages 6,000,000 tons per year. About 600,000 tons of this are used for planting. The hulls are used for bran and fuel and sometimes are made into paper fibers. Oil is extracted from the seed kernels and the remainder is converted into feed and fertilizer. The value of linters and seeds materially reduces the price that must be charged for the cotton fiber or lint cotton.

A farmer may have one or many bales of cotton for sale, and the average per farm is five bales. When the farmer receives a bale of ginned cotton he generally drives directly to the market square to dispose of it. Many independent buyers will be found in a market of any size. The price they can pay is determined by the individual or organization they repre-

sent. The producer knows something of the general price being paid for cotton, but he is seldom able to judge correctly the grade of the cotton he has for sale. Therefore the price the grower receives is determined to a great extent by his ability as a bargainer. The average price per pound for cotton, through several years, was from 10 to 15 cents, but in 1946 this rose to 36.9 cents. The first buyer the farmer meets cuts the bale, pulls out a sample of cotton, and makes an offer which is seldom accepted. The second buyer asks the price quoted and may or may not raise it. When a sale is made, the farmer is given a ticket of sale which he presents at the bank or place designated and receives his pay. The buyer in the local market often resells his cotton at the end of the day to another local buyer or an outside man. The local market furnishes the producer a ready means for the disposal of his cotton and begins the assembling of the season's crop. (See the illustration on page 287.)

Classification. The quality of cotton varies from one farm to another and even in that produced on one farm. The variety planted, variations in soil, rainfall, temperature, cultivation, harvesting, and ginning methods are the causes of variation in quality. Because the manufacturer requires uniformity in the raw material with respect to grade, staple length, and quality, it is necessary to classify the cotton according to these properties.

What constitutes quality? The quality of cotton has been defined as the physical characteristics which affect its usefulness. The principal characteristics which affect quality are staple length, uniformity of fineness, and maturity.

Cotton is graded according to its color, foreign matter, and ginning preparation. Grade refers principally to noncotton elements—particularly to effects produced upon cotton fiber after the boll has opened in the field.¹

Cotton standards. The official cotton standards of the United States for grades and colors of American upland cotton (known as the universal standards of American cotton)

¹ "The Classification of Cotton," U. S. Department of Agriculture, Bureau of Agricultural Economics, Miscellaneous Publication No. 310.



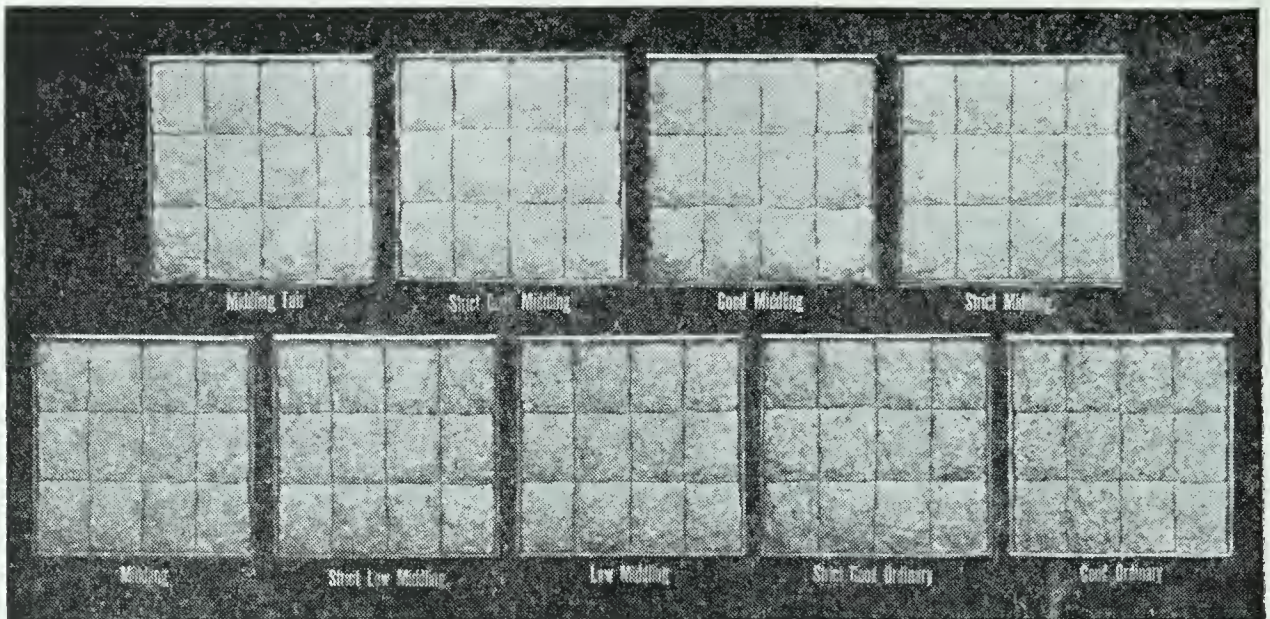
Courtesy Texas A. and M. College Extension Service

Cotton at the gin.

are prepared by the Bureau of Agricultural Economics of the United States Department of Agriculture.¹ (See page 288.) Copies of these standards are seldom found in the local markets. The local buyer bases his judgment upon experience. Cotton is also graded as many times as it changes hands. In grading, samples are drawn from each side of the bale. If there is a difference, the cotton is given the lower grade.

The basis for grading or the standard by which all the other grades are measured is designated as "middling." This is nearly white in color and contains only a small amount of foreign matter. There may be nine or thirteen or more grades ranging above and below the standard middling. Excessive rainfall, soil conditions, unfavorable weather such as early frost, and the like, affect the color of the cotton. The addition of the words tinted, tinged, or stained, to the commercial grade, indicates the amount of discoloration of the fibers. The commercial value of cotton is determined by the grade, which is based upon its color and the percentage of foreign matter

¹ Alonzo B. Cox, "Services in Cotton Marketing," U. S. Department of Agriculture, Department Bulletin No. 1445, p. 11.



Courtesy Bureau of Agricultural Economics, U. S. D. A.

Set of official cotton standards.

it contains. The cotton that enters a local market may vary in value through wide limits; however, there is not enough business in one of these markets to justify the employment of skilled classers. The local buyer sells direct to a merchant or to his agent. After the cotton is bought from the farmer it is handled in large quantities according to grade but generally goes through many hands and many markets before it reaches the spinners' market or the factory.

PROBLEM 2. HOW DO TYPE OF COTTON AND GEOGRAPHIC SOURCE INFLUENCE THE QUANTITY OF COTTON PRODUCED?

Botanically there are but three groups of cotton of commercial importance. The bulk of the American cotton is the upland cottons which have been developed from cotton native to Mexico and Central America. These vary in length from $\frac{3}{4}$ to $1\frac{1}{2}$ inches. Sea Island, American-Egyptian, and a few Peruvian and Brazilian varieties make up the longer-staple varieties and are $1\frac{1}{4}$ inches or more in length. A third type includes the short-staple cottons native to India and eastern Asia. According to the *Textile World*, there are at present less than 100 varieties of cotton of which not more

than 30 are commercially important and six make up 34 per cent of the United States production. These may be grouped into half a dozen variety types such as Sea Island, American-Egyptian, Acola, Long Staple Upland, Medium Upland, Short Upland and the Texas High Plains Variety.¹

Only a few thousand bushels of the American crop are American-Egyptian and Sea Island. American-Egyptian is grown principally in Arizona, and Sea Island is produced in small quantities in Georgia and Florida.

Long-staple upland is grown in the delta areas of Mississippi, Arkansas, and Louisiana, and in California, New Mexico, and South Carolina.

Until 1932 the United States dominated the world market for raw cotton, producing upwards of 60 per cent of the world cotton crop. In the past few years the production of American cotton has decreased and there has been an increase in the production of cotton in other countries. This means that the United States has lost its dominating position and is being supplanted by other countries and that much of the domestic cotton which has always been exported does not find a buyer. The five important foreign countries producing cotton in order of importance are India, China, Russia, Egypt, and Brazil.

The reported cotton production for 1945 in the United States was a decrease of approximately 17 per cent from that produced in 1944. However, the yield per acre increased to 269.7 pounds. The average yield for China has been estimated as 200 pounds; for Russia, 212 pounds; and for Egypt, over 400 pounds.

Acreage in India and China is limited because of the famine factor, which requires that 85 to 90 per cent of the crop areas be used for food crops.

The cotton situation in Brazil has changed greatly. With the collapse of rubber and coffee the cotton industry developed with amazing rapidity in the southern part of Brazil. The old cotton land of Brazil is in the northern part where

¹ "Tests Show Best Cotton for a Specific Purpose," *Textile World*, Vol. 95, No. 12 (1945), p. 99.

the tree-cotton variety has been produced. The southern part has a climate, soil, and rainfall peculiarly fitted for production of American upland cotton and is being given over largely to its cultivation.

Sea Island is one of the most important varieties of long-staple cotton. According to some authorities Sea Island was first found in the United States; others say it originated in the Bahama Islands and was brought from there to the United States. This type of cotton develops best along the sea where there is plenty of moisture and salt air. It has, however, been successfully produced in the irrigated districts of Arizona and California. Sea Island, which is characterized by its length, fineness of staple, and the uniformity and number of spirals per inch, averages from $1\frac{1}{2}$ to 2 inches in length, is silky, and is creamy white. Because of its greater length and small diameter this cotton is probably the most valuable variety for use in the manufacture of thread.

The production of this type of cotton is being revived in the United States within the past few years, but so far the entire crop is only a few thousand bales.

Consumption and production in the United States. Much of the imported cotton consumed in the United States is from Egypt. As much as ten million dollars' worth of this cotton is imported annually to meet special manufacturing needs. It is used principally for mercerization and in the manufacture of thread, knit goods, lace, automobile tires, and fabrics for the rubber trade. Egypt has an excellent climate, splendid water supply, and other conditions favorable to the production of a good type of cotton. The brownish color of much Egyptian cotton is caused by the red coloring matter in the waters of the Nile.

Rough Peruvian cotton is characterized by its similarity to wool in feel and appearance. This cotton is imported into the United States to be mixed with wool.

In the United States too little attention has been paid to the quality of the seed planted, and in some parts of the country the crop has also suffered for want of care. Cotton growers are

now being encouraged to decrease the acreage, use only certified seed, and give the crop proper care and cultivation.

The boll weevil worked great havoc to American cotton growing, practically destroying the Sea Island cotton and spreading over a great part of the upland cotton fields. The larvæ lie dormant during the winter, sheltered by weeds and tall grass, and then develop in the spring. They bore into the cotton boll and destroy the fiber. The development of rapid-fruited, early-maturing varieties has in a measure solved the boll weevil problem.¹

The United States government offers the following figures as showing the number of units of specified cotton articles in general use that are ordinarily obtained from twenty-five pounds of raw cotton: ²

ARTICLE	NUMBER
Overalls	12
Work shirts	35
Sheets	13
Pillowcases	60
Automobile tires	5
Cement bags	50
Percale, piece goods (sq. yds.)	110

It is estimated that, during recent years, for each man, woman, or child in the United States, something like 10 pounds of cotton, on the average, were used annually for clothing and about 5 pounds for household purposes. This leaves an estimated 10 pounds used for industrial purposes. These figures indicate the extent to which the total outlet for cotton in this country has become dependent upon industrial uses.

Although clothing and household uses still constitute the bulk of the requirements for cotton, the industrial field of uses

¹ "Plant Breeding and the Cotton Industry" (Reprint of pages 657-744), U. S. Department of Agriculture, Yearbook Separate No. 1578 (1937), p. 663.

² E. H. Pressley, Rodney Whitaker, and George W. Ban, *American Egyptian Cotton*, University of Arizona College of Agriculture, Agricultural Experiment Station Bulletin, No. 167.

has continued to expand notwithstanding competition from jute, paper, and other materials.

PROBLEM 3. WHAT ARE THE MICROSCOPIC AND PHYSICAL PROPERTIES OF THE COTTON FIBER?

We would expect cotton to have the ideal fiber qualities since it makes up practically three-fourths of the fabrics used. On the contrary, cotton is the least elastic of the five common fibers, has the lowest luster, and is the least resistant to the effect of exposure to the elements. The comparatively low cost per pound of this fiber has been a great factor in its wide use. At the present time rayon yarns can be produced at a lower cost than cotton yarns of the same quality, and although cotton is the most satisfactory fiber for many uses it is being replaced by other fibers for numerous articles.

The several vegetable fibers of more or less importance in the textile industries are classified according to the part of the plant in which they are found, as seed hairs, bast, and leaf fibers. Cotton is the seed hair or fiber that surrounds the seed of the cotton plant.

Microscopic properties. The microscopic appearance of the cotton fiber serves as one of the best means of identification. The twisted condition and thickened edge are usually easily seen, even in the most highly mercerized specimens. (See page 293.) The cotton fiber is unique in that it appears to consist of a single cell. However, high magnification shows the structure to be exceedingly complex. The central canal or lumen is surrounded by a wall made up of many concentric layers of material. The cotton fiber is not homogeneous.

[It] is composed of layers of fibrils which are cemented together with a pectic substance. The fibrils, in turn, are made up of small cellulose particles which are bound together by the non-cellulose pectic material. In the outer portions of the fibril, the cellulose particles occur in the form of long bead-like chains; in the center portions, the particles occur both as short chains and separately.¹

¹ "What Is Cotton?" *Textile World*, Vol. 86 (1936), p. 74.

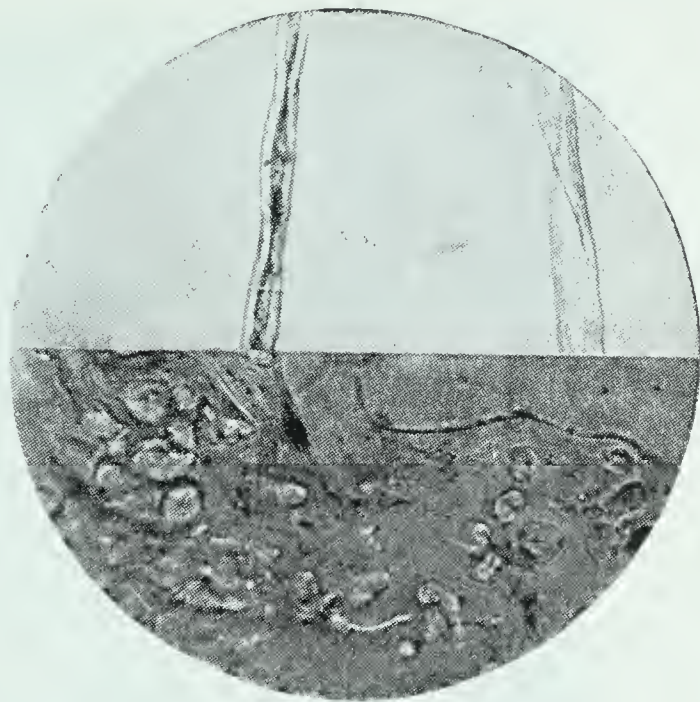
The minute structural characteristics of cotton determine to a large extent the ability of the fiber to withstand the processes of manufacturing to which it is subjected. It would be difficult to spin cotton into a continuous length of yarn were it not for its natural twist or spirals. The twist of mature cotton varies from 150 to 300 turns per inch. Immature cotton fibers do not possess

this twist, are weak and brittle, and are difficult to dye. The presence of immature fibers is objectionable since it reduces the spinning quality and dyeing property of the stock. The cotton fiber is attached to the seed at one end, and the outer end is free. While growing, it is cylindrical with a pronounced central canal or lumen filled with plant juices.

The cotton fiber is most unusual in the method of its growth. It reaches its full length and circumference in the first part of its development, usually in about twenty days, and then a layer of cellulose is deposited each day within the outer shell or primary wall. It requires about forty-five days for complete development. The maturity of cotton is dependent not on whether it is ripe or unripe but upon the comparative thickness of the cellulose wall. Much research has been done in an effort to develop early-maturing cotton types.

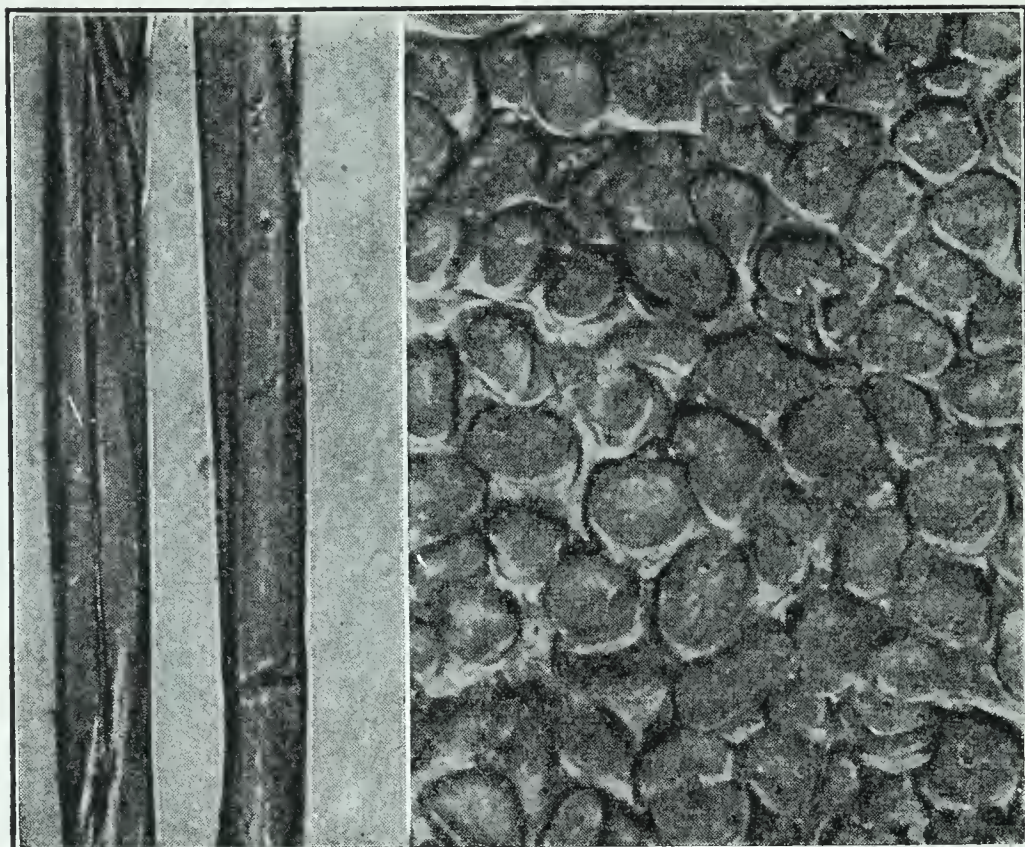
Polarized light serves as a convenient means of determining the degree of maturity of cotton fibers. Under this light the mature fibers are blue and the immature fibers are green, with all gradations of color between these two.

When the boll bursts and the fibers are exposed to the light and air, the juices dry up and the cell collapses, leaving a more



Photomicrograph by Schwarz

Cotton fiber, showing longitudinal and cross section.



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Longitudinal and cross section of mercerized cotton.

or less flattened fiber which is twisted upon its axis. The thick cell wall and characteristic twist can be seen easily with low magnification, and this method is a means of identifying cotton fibers.

Physical properties. Usually the cotton is creamy white, although most Egyptian cottons have a yellowish-brown cast due to pigment transferred from the soil. Blue-bender cotton, grown along certain rivers in some of the southern states, possesses a peculiar blue tint which is difficult to remove by bleaching. Other types that have been recently developed are quite dark in color.

Staple cotton is cotton that is $1\frac{1}{8}$ inches or more in length. Staple refers primarily to the length of the fiber but is regarded as indicative of the other characteristics. As a rule the longest fibers are the finest, contain the greatest number of twists per inch, and in general are the most valuable. The spinning value of the fiber is determined by physical qualities such as elasticity, cling, fineness, and luster. These character-

istics, which influence the commercial grading of cotton but slightly, are indicated by the staple.

The classing of cotton is based not only on the grade but also on those qualities that determine the spinning value, and hence furnishes a basis for sorting the cotton so that the spinner may obtain what he wants. After the cotton is classed, types are made up according to the classes handled. The use of these classes eliminates the cost of many handlings of the cotton.

Cotton stands between silk and wool in tensile strength. The elasticity of cotton is less than that of either silk or wool. Vegetable fibers are heavier than the animal fibers. The density of cotton is about 1.5. Cotton is low in hygroscopic qualities. It becomes brittle and inelastic when dry and increases in both strength and elasticity as the percentage of moisture increases.

In order to make the structure impervious to water, nature has coated the cellulose building blocks with molecules of wax. This wax plays an important role in the spinning and finishing processes. In order to soften the wax, a temperature higher than ordinary room temperature is maintained in the spinning room. Fibers from which the wax has been removed cling to the drawing and finishing frames, producing an excess of waste.

The percentage of moisture in the fiber has a great effect upon its spinning qualities. This among other reasons accounts for the fact that the cotton mills remained in New England until the development of humidifying apparatus made practical the maintaining of constant humidity in the factories. In cotton the allowable regain is from 6 to 8 per cent.

Cotton soils and crushes easily but can be washed and ironed without injury, as the use of boiling water and a weak alkali and soap do not materially affect it. Cotton is the one fiber that will withstand much rough handling, high temperatures, and boiling water. For this reason cotton is considered by some as the most hygienic fiber, being practical for household articles and garments that are laundered either commercially or at home.

Uses of cotton. Much research was carried on in an effort to replace linen and silk with cotton for aircraft fabrics. These investigations resulted in the production of a cotton cloth which proved more satisfactory for airplane wing coverings than the linen that had been previously used. Experimental work has been done in an effort to produce a cotton fabric for parachutes. Commercial chutes of this material can be bought, but they have not been accepted by the army and navy of the United States. Investigations of this kind usually result in improved methods of manufacture and the production of better fabrics for other uses, and generally result in an elimination of waste with an accompanying reduction of cost.

Improved machinery and methods for manufacturing have reduced the cost, and new finishes permit cotton to compete with jute, other fibers, and paper in the production of inexpensive articles.

Permanent water repellent, crease resistant, and starchless finishes give to cotton fabrics qualities they do not naturally possess. These finishes are discussed in Section III.

Doubtless you can list several other new articles for which cotton has recently been found suitable. The present need is perhaps not only for new uses for cotton but also for cotton fabrics to be fashioned to compete in style with fabrics made of other fibers. Even more important seems to be the need for dresses made of cotton that are styled and tailored to compete successfully with dresses made of other fabrics.

Suggestions for the Laboratory

Study longitudinal and cross section of cotton fibers. Note the difference in twist and maturity.

Study cotton fabrics of various types. These should include material for both clothing and household use.

PROBLEM 4. HOW IS COTTON YARN MANUFACTURED?

The cotton that the yarn manufacturer demands is determined by the type of finished product he is making, but the fiber must possess a definite spinning quality.

The construction of a continuous length of yarn from short fibers is described in Problem 2 of Unit Two, which uses the cotton fiber as an example of this process. In this discussion the processing of cotton yarn is followed through its many steps from the bale to the finished product. The type and quality of a fabric are determined to a great extent by the type and quality of the yarn which is used in its manufacture.

Cotton yarn varies greatly: it may be coarse or fine, soft or hard twisted, or even twistless; it may be combed or carded; it may be of single or multiple ply; and simple or complex.

Practically all cotton yarn is twisted. This is because the twist is required to hold the short fibers securely in the strand. Twistless cotton yarns have been successfully constructed and found practical for use as weft yarns and for knitted materials. One method for preparing these yarns has been to apply adhesive to ordinary cotton yarns of the desired count and then spin the yarn in the opposite direction, thus removing the twist.

Another process produces a twistless yarn by the use of adhesive only. This method permits the fibers to be parallel and thus increases the luster and softness of the yarns and fabrics made from them. A third method has been developed by which yarns with about half the ordinary amount of twist have been spun without the use of adhesive. When adhesive is used it is removed in finishing. Where adhesive has not been used no special scouring is necessary.

These twistless yarns have the advantage of luster, covering power, and softness. Because of the increased covering power a fabric with fewer yarns can be produced, thus lowering the cost of production. In the United States the number or size of cotton yarn is usually expressed as the number of hanks of 840 yards each in a pound.

PROBLEM 5. WHAT ARE THE CHEMICAL PROPERTIES OF COTTON?

A cotton fiber is an elongated cell, constructed from millions of cellulose molecules. Small amounts of moisture, of

fatty material, and of mineral ash are constituents of cotton. This fiber, built largely of cellulose, ignites easily and burns with an odor similar to that of burning wood. Litmus paper, held in the fumes of burning cotton, turns red indicating the presence of an acid. It burns with a bright flame which continues after being removed from the fire. After the flame has been extinguished the fibers continue to smolder and smoke. This is typical of cellulose. When heated out of contact with air, the cotton cellulose molecules break down to form gaseous hydro-carbons, methyl alcohol, acetic acid, and carbon dioxide.

Violet and ultraviolet rays. All cellulose fibers are somewhat sensitive to violet and ultraviolet rays. Heerman conducted a series of experiments to determine the effect of light upon different fibers.¹ He exposed specimens by placing them 16 centimeters from a 1,600 candle-power mercury-arc lamp for definite periods of time. Linen showed less loss in strength than cotton. Bleached-mercerized cotton withstood the rays more successfully than unbleached or bleached cottons. Viscose and nitro-cellulose rayons were tendered to about the same extent as cotton, cuprammonium rayons a little less. In all cases the cellulose fibers suffered a loss in strength of 50 to 70 per cent after twenty-four hours' exposure. Tendering was caused by the formation of oxycellulose. An example of this tendering is seen when curtains made of cotton on prolonged exposure to the sun become tender and fall apart when laundered.

Alkalies. The action of alkalies seems to have been noted first in 1884, when a Lancashire calico printer found that some cotton material through which he attempted to filter a concentrated sodium hydroxide solution shrank and became transparent. Mercer worked on the discovery and a few years later took out a patent for the mercerizing process. He treated the material for a short time with cold concentrated sodium hydroxide, then rinsed it thoroughly in water, obtaining a material which had a rough, uneven surface, increased

¹ George H. Johnson, *Textile Fabrics*, pp. 310, 312. Harper and Bros., New York, 1927.

strength, and greater affinity for dyes. He failed to notice that the material, if held under tension during the rinsing process, did not shrink, was more elastic, and had a smooth, highly lustrous surface unlike the untreated material.

Mercerization. Mercerization is accomplished by treating cotton under tension with a strong solution of sodium hydroxide. By this means the luster is increased, the cotton is strengthened, and there is an increased affinity for dye.

The change that takes place during mercerization is mostly a physical one, although there is also some chemical change. Although some alkali-cellulose is probably formed during mercerization, cellulose is regenerated during the washing process. The physical change results from the swelling of the fiber which removes the twist and closes up the medulla so that the fiber becomes practically cylindrical.

Yarns in warp and even skeins are mercerized, but most mercerization is done in the fabric form. A mercerization unit includes two 3-bowl mangles, a tenter frame, and boxes for washing and scouring, set up in continuous form.

At ordinary temperatures dilute alkalies are not injurious to cotton. If boiled in a dilute solution of alkali in the presence of air, the cotton becomes yellow and shows a slight decrease in tensile strength due to the formation of oxycellulose. These reactions may occur during the process of home laundering if the clothes are not kept under water while boiling.

Neutral salts, ordinarily, are not harmful to cotton. Acid salts, such as acid sodium sulfate, or salts which hydrolyze to form acids, have the same harmful effect upon cotton as the acids, especially at higher temperatures. Basic salts are not harmful, hence are often employed as mordants.

Acids. Cotton is sensitive to acids, unless the conditions of application are carefully regulated. In general, mineral acids cause cotton to disintegrate. The higher the temperature is the more rapid the destruction. Dilute acids, if washed out immediately, cause little harm, but if the acid is allowed to dry on the fiber, thus becoming more concentrated, the material falls to pieces. The acid reacts with the cellulose to form

hydrocellulose, which is an easily powdered, structureless material. Acid is used in the carbonization process to disintegrate the cellulose portion of the wool and cellulose mixture. Parchment paper is made by treating the cellulose sheet with cold concentrated sulfuric acid for a short time. The paper becomes somewhat transparent and no longer absorbs grease and water.

Volatile organic acids, such as acetic, do not cause tendering, and therefore may be used in cotton finishing processes. Tartaric and other crystalline organic acids crystallize within the fiber and break the cell wall, thus decreasing the strength of the material.

Immunized cotton. In contrast to the mercerization of cotton which is done to produce a more reactive fiber, thus increasing its affinity for dyes, cotton is immunized to produce a fiber that is more resistant to certain dyes. This permits its use as effect yarns in piece-dyed fabrics. In this treatment cotton, usually in yarn form, is esterified with an aromatic sulphonic acid chloride. This results in each fiber having an outer layer of a cellulose ester which resists direct dyes. In most cases the cotton increases from 15 to 20 per cent in weight.

Developments in the processing of cotton. Recent developments in the field of yarn and fabric finishes provide encouragement for those who question the ability of cotton to compete with synthetic fibers. Research and wartime experiences have vastly increased the range of usefulness of cotton goods.

The cotton fiber can certainly have a much wider range of usefulness if a greater portion of its strength can be utilized. An equal advantage can be gained by improving other properties such as softness, luster, resilience, resistance to absorption, mildew, mold, fire, and creasing. Chemical and resin research has been developed whereby each of these properties of cotton may be improved. Any such improvements must of course last as long as the fiber itself.

A new market for cottons is provided by the plastic industry. It has been proved that cotton is a satisfactory filler or reinforcement for those plastics which combine high tensile

strength with light weight, toughness, flexibility and moldability. This is especially true of laminated plastics which are built up of layers. More than 75 per cent of the filler used in laminated plastics is cotton fabric. In 1943 approximately 50 million pounds of cotton textiles, representing 110 thousand bales of raw cotton, were used in the production of cotton laminates.

The automotive, aircraft, office equipment, building construction, and house furnishings are among the industries in which laminated textiles will find extensive use. Walls and partitions, shingles, moldings and baseboards, Venetian blinds, refrigerators, pianos and bathtubs are some of the items manufacturers are planning to make of plastics.

Carded cotton fibers in web form have been successfully used as filler for laminated plastics. The use of the carded web would greatly reduce the cost and thus enhance the competitive position of cotton in this field.

Bonded cotton yarn. Much research has been directed toward the production of a stronger cotton yarn. Not more than 35 per cent of the combined strength of the raw fiber is realized in the spun yarn. Industrial yarns of greater strength are demanded in the widely expanding field of industry. The rapid development in the field of polymerization in which many new compounds have been produced has resulted in the use of some of these products to more fully utilize the combined strength of the fibers in yarns.

Cotton fibers, although seldom an inch long, are from 2,000 to 4,000 times as long as they are wide. When fibers are twisted in the construction of a yarn, the outer fibers receive most of the twist and tend to grip the fibers in the center which are practically without twist. The longer the fiber in proportion to its cross section the more strength that is gained by this grasping of the fibers in the center of the yarn. Strength is dependent also on the maturity of the fibers. The uniformity of the fibers is another important factor in the production of a strong yarn. The improvements in the quality of the cotton fibers as the result of selection and breeding will no doubt be carried still further, but any treatment that

can be given to cotton roving or yarn that will result in an adjustment of the individual fibers so that each can bear its own portion of the strain will greatly increase the ability of the yarn to resist rupture.

A bonding treatment has been developed wherein the yarn is rendered plastic during the stretching processes and then set by heat or other means so that the friction is greatly increased. There are hundreds of synthetic compounds with widely differing characteristics from which the most suitable one may be selected to meet any predescribed specifications. These may be thermoplastic or thermosetting; they may be combined with color or with chemicals to resist mildew, mold, or fire. It has been suggested that these special treatments may be given to the roving. Then a strong yarn may be produced without carrying it through the spinning and doubling processes.

The light-weight, wind-resistant, water-repellent cotton fabrics developed during the recent war were found to provide warmth without weight. The water-dispersed coating of resins used for this purpose penetrates the fibers and results in a very strong fabric. This type of finish can be applied by textile finishing mills which were not equipped to handle the old type of water-repellent finishes. These fabrics will in many instances replace wool cloth for coat material.

CHARACTERISTICS OF COTTON FIBERS

Microscopic appearance. . .	Longitudinal—twisted ribbon with thickened edges Cross section—varies from flat to circular
Length.	$1\frac{1}{2}''$ – $2\frac{1}{2}''$ —from 2,000 to 4,000 times its width
Diameter.	16–20 microns
Color.	White to cream
Luster.	Low
Strength.	2.6 grams per denier (4–12 grams per fiber)
Elasticity.	Low

CHARACTERISTICS OF COTTON FIBERS

Conductor of heat	Good
Effect of heat	Resistant
Water absorbency	Low
Standard regain	7%
Effect of moisture	Increases strength and reduces elasticity
Effect of sunlight	Slowly deteriorates
Attack by mildew	Untreated not easily attacked. Starches and gums increase activity
Attack by moth	No
Effect of acids	Concentrated acids destroy
Effect of alkalies	Strong alkalies do not injure Weak alkalies do not injure

Resilient cottons. The development of cotton suitings with greater resilience and therefore with greater ability to hold their shape would increase the usefulness of cotton fabrics. This type of fabric can be produced by finishing with certain types of melamine resins. Fabrics given this type of permanent finish not only resist creasing, but the creases tend to hang out in a comparatively short time.

This same type of finish would aid cotton blankets to maintain their thickness and hence their warmth. Freshly napped cotton blankets are warm because of their thickness and the dead air spaces they contain, but the nap tends to mat or crush due to use and cleaning and thus the blankets lose their warmth. A finish that would give to cotton blankets an increased resilience would enable cotton to better compete with wool in blanket fabrics.

Recent work has indicated that the luster, body, and washability of cotton can be permanently improved by the use of resins. Cottons finished in this way retain their crispness during wear and after laundering. These finishes combined with an improved resilience would permit cotton to compete with all natural or synthetic fibers for use in the clothing and textile field.



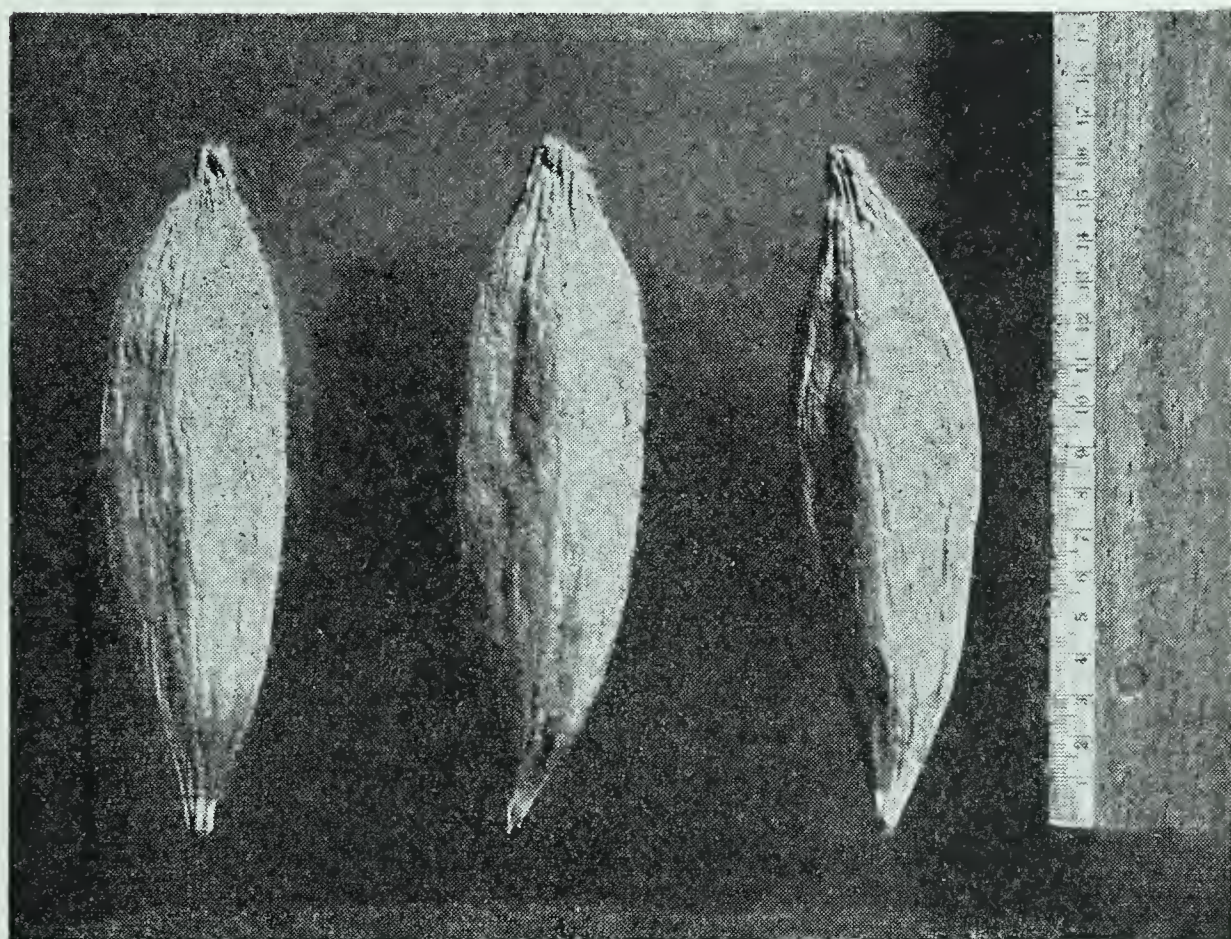
Courtesy Netherlands Indies Government

A kapok plantation.

PROBLEM 6. OF WHAT IMPORTANCE ARE KAPOK AND MILKWEED FIBERS?

Kapok. Kapok is a silky fiber obtained from the fruit or pods of the kapok tree. This tree is grown principally in Java and South-Celebes in the Netherland Indies. Here the soil and climatic conditions are especially suited to its growth.

The pods are oblong in shape, from four to six inches in length, and one to one and one-half inches in diameter. (See page 305.) The fibers are contained in the outer shell. When the fruit or pod is ripe the fibers are in small clumps loosely surrounding the seeds and entirely free from the shell. Sunshine and air cause the clumps to open out into a large, loose mass. The pods are harvested as soon as they are ripe, the fibers being separated from the seeds by hand. The unripe pods are carefully eliminated and great care taken to assure a product as free from impurities as possible. To produce 100 pounds of pure kapok, from 10,000 to 11,000 pods are required. The fiber is shipped in hydraulically pressed bales, covered with mats or with burlap, and bound with iron hoops.



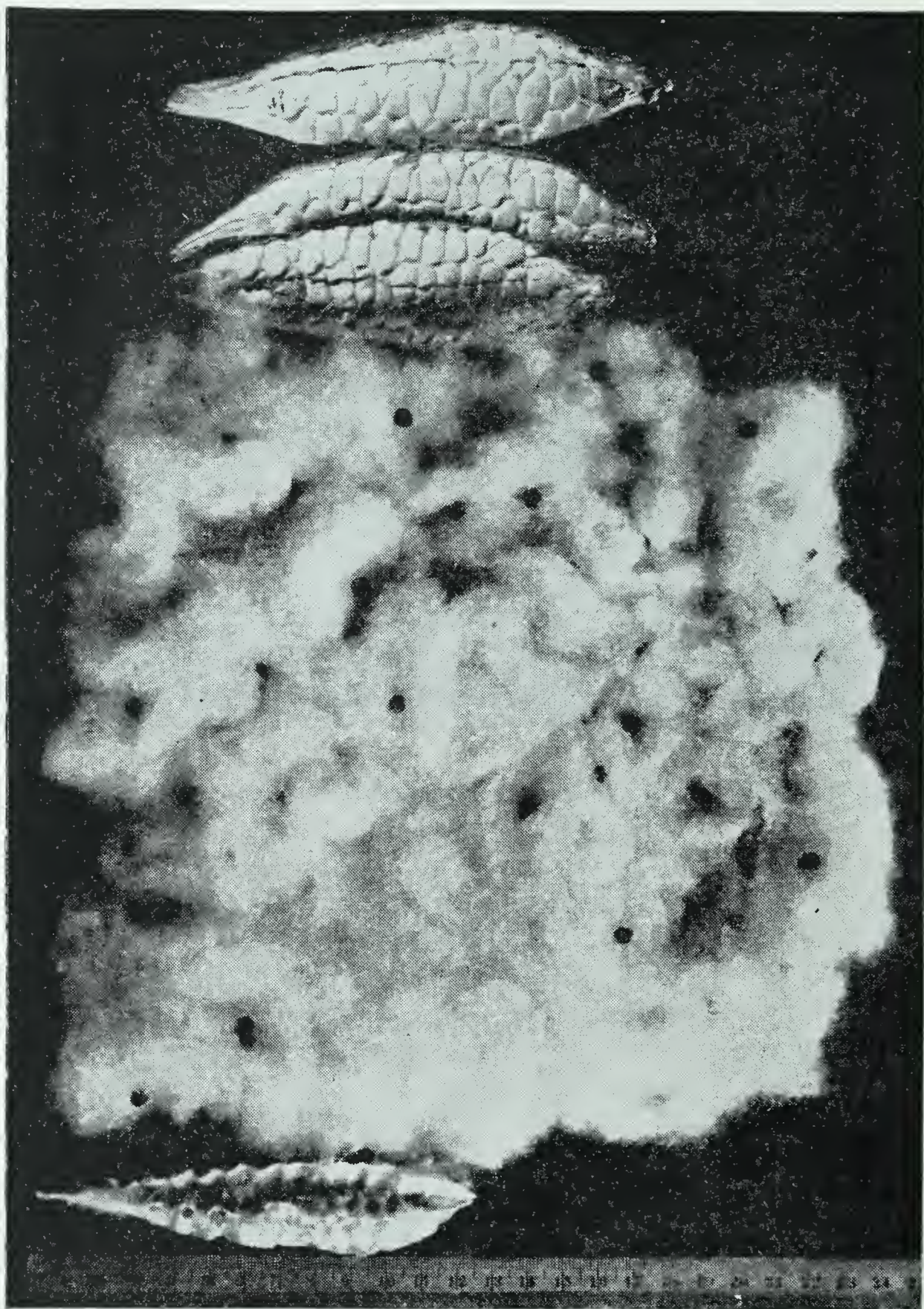
Courtesy Netherlands Indies Government

Ripe pods of kapok shown against a metric scale.

The kapok fiber is white and silky. (See page 306.) The thin-walled, air-filled cells are covered with a waxy substance which renders the fiber impervious to moisture and also vermin-proof. These air-filled cells (See page 307.) give the fiber its peculiar buoyancy. They act as air cushions; hence it is especially suited for use where insulation or absorption of vibration is desired. Care should be taken in handling kapok to prevent the destruction of the air cells.

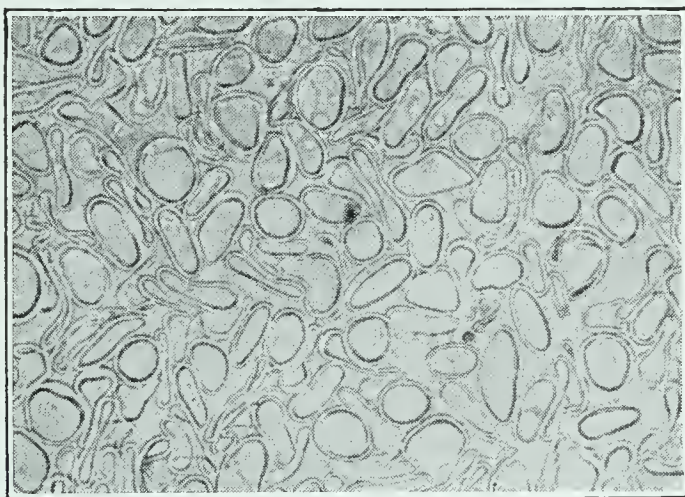
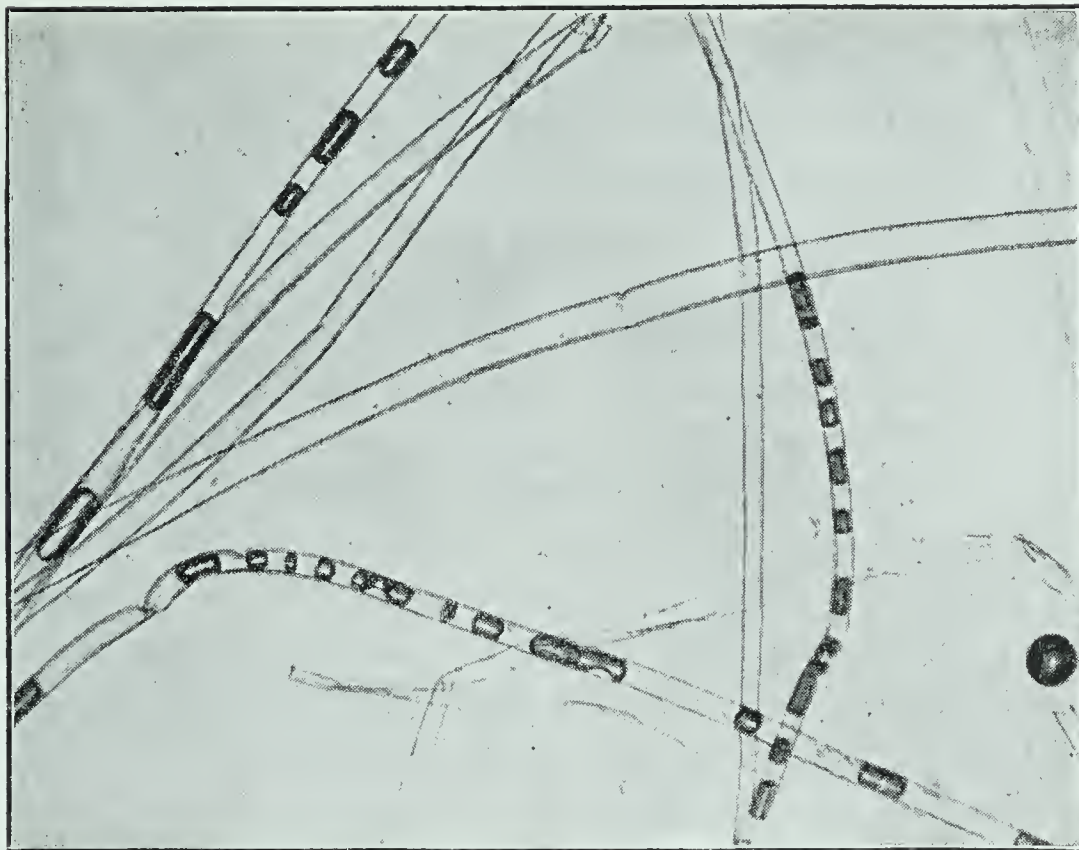
This fiber does not lend itself to the construction of yarn because the fibers are short and straight. Its buoyancy and resiliency naturally cause the fibers to separate rather than cling together. However, some progress has been made in spinning it into yarn.

Milkweed fiber. When it became difficult to obtain kapok fibers during the recent war, many experiments were carried on in an effort to replace them. For this purpose, viscose rayon was spun into a fiber containing pockets of air. It was found



Courtesy Netherlands Indies Government

At top, open pods of kapok showing arrangement of floss within the pod; center, floss after removal from pod and fluffing-up; bottom, core.



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Longitudinal and cross section of kapok.

that the fiber best suited for use as a substitute for kapok was milkweed fiber. An examination of the two fibers shows a striking resemblance. Both fibers have the same wide lumen and thin walls. They are almost the same size in diameter and length. The physical characteristics of high sheen, lightness, and softness of the two fibers are practically identical. The buoyancy of the two fibers is the same, and the insulating properties of the milkweed fiber are slightly superior to those

of kapok. Neither fiber retains moisture nor is readily wetted by liquids and both are vermin-proof.

The lack of mechanical means of separating the milkweed floss from the seeds prevented its use in the past. A milkweed gin has been developed which can successfully remove the fibers from the seed so that this fiber can now compete economically with the kapok fiber harvested and handled by low-priced foreign labor. Milkweed fiber is the one American grown fiber that is suitable for use in life preservers. As this fiber is a better insulating material than wool it has been used in clothing for the armed forces, especially the Navy. It is estimated that three pounds of milkweed floss in the lining of a coat would keep the wearer warmer than any other insulating material, and in case of shipwreck would keep him floating for 100 hours. There are other valuable products of the milkweed plant which will make it an economical crop, and the utilization of the plant for soil conservation purposes may make it one of the most important crops in the United States.

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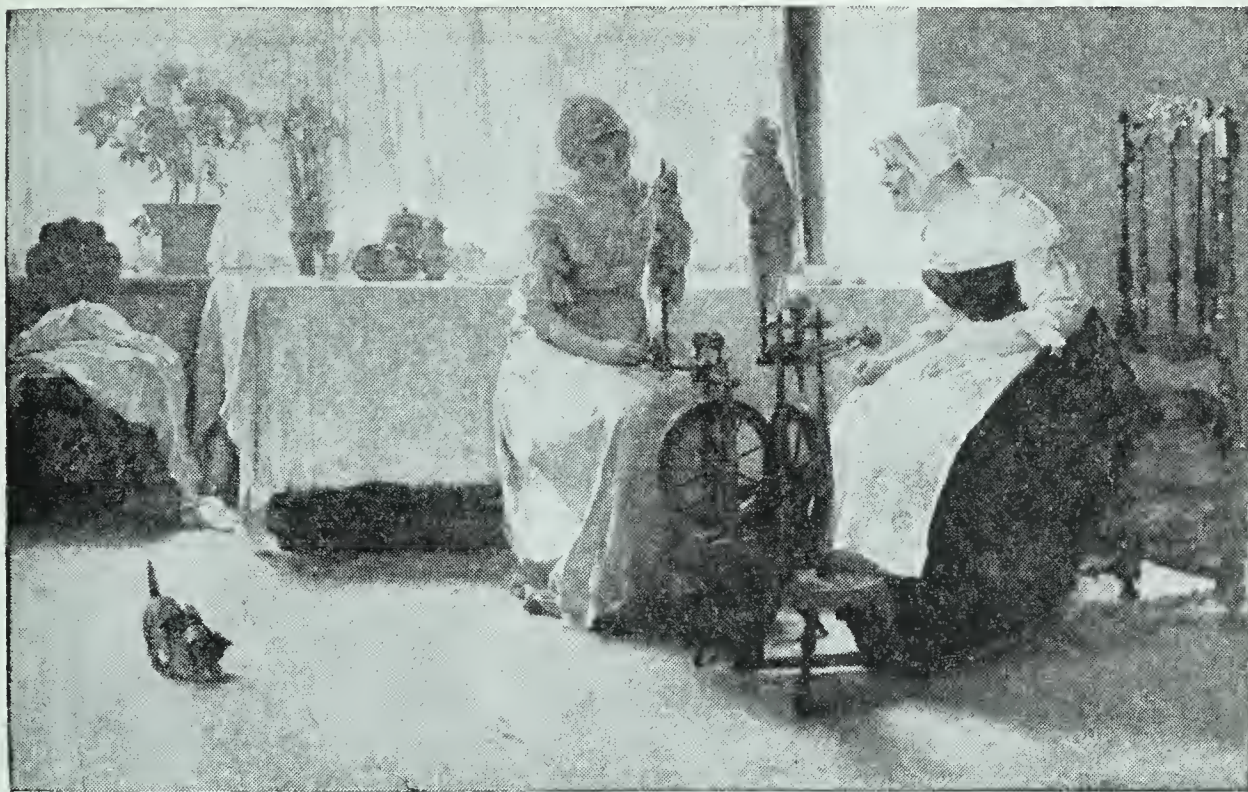
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Unit Five

LINEN AND OTHER BAST AND LEAF FIBERS

IN AMERICA as well as in other countries linen holds a position of respect not accorded most fibers. "Fine linen" has always been associated with ceremony and ease. The origin of linen is not known, but it probably came from the East. It has historical interest because of references to it in the Bible and other early records. Linen had a place in the religious rites of the ancient peoples which it still holds with some religions today. Mummy cloths of linen, used to wrap around the dead, have been discovered that are thousands of years old. In former days the robes of pomp and ceremony of church and state as well as the funeral robes were all made of linen fabrics. Thus linen occupies a unique position as a textile fiber. At one time this flax fiber, or linen, was raised, spun, and woven in practically every American home. (See page 311.) With the development of the factory system cotton replaced linen and today the amount of fiber flax produced in the United States is comparatively small. However, the development of harvesting machinery and new processing methods is permitting flax to be again produced economically in the United States.

The production of flax is divided into two separate industries: the production of fiber and the production of seed for oil. The plant that is grown for fiber produces seeds that have commercial value, and the plant that is generally grown for the oil yield of its seeds produces a fiber suitable for spinning the coarser yarns.

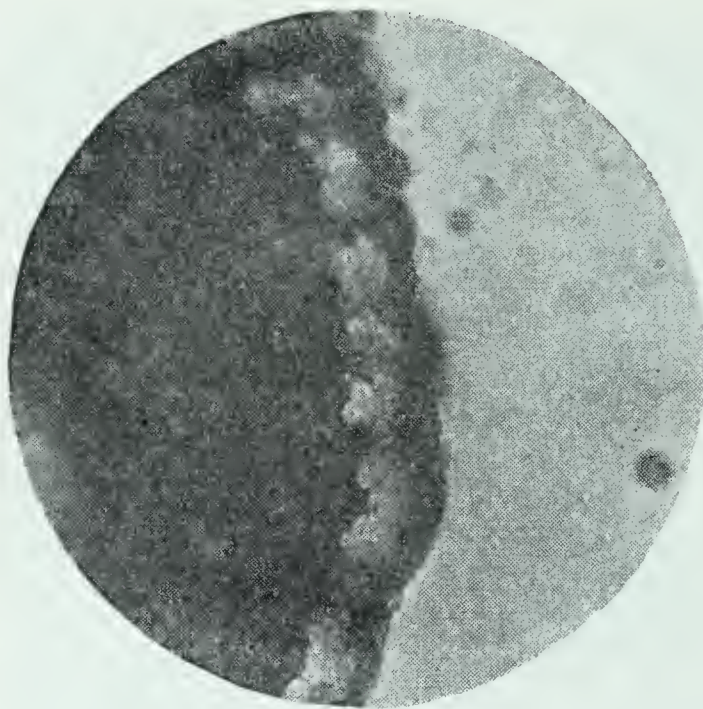


Courtesy The Metropolitan Museum of Art

"Gossip," by Carl Marr.

PROBLEM 1. HOW IS THE LINEN FIBER PREPARED FOR USE IN THE INDUSTRIES?

The linen fiber is a bast fiber found in the stem of the flax plant. (See page 312.) It grows in bundles that surround the central woody part of the plant and serve as an inner bark. The growing of the flax plant and the preparation of the fiber for use require much work. The processing of the fiber requires special machinery and expert knowledge. About 1830, when the spinning and weaving of textiles went out of the American home into the factories and homespun were replaced by factory-made cloth, linen was replaced by cotton as the fiber most used for clothing and fabrics for household use. This was because the technique of the production and processing of the linen fiber did not develop as did that of other fibers. Until recently these processes remained practically the same as those in the time of Pharaoh. In 1914 when the supply of flax from Russia was shut off, the English-speaking nations of the world were compelled to replace hand processes with machinery wherever possible. Today in some countries



Photomicrograph by Schwarz

Cross section of flax plant, showing bundles of fibers.

many of the processes are still done by hand, but machinery has been developed that successfully handles the fiber, eliminating many hand processes.

Growing and harvesting of seed flax. The flax plant is delicate and requires careful attention. It grows best in a cool, damp climate and rich soil.

The fine root tendrils will penetrate the soil to a great depth if the ground has been sufficiently prepared. This makes it necessary to plow deeply and work the soil thoroughly.

It has been definitely proved that a crop of flax removes less plant food from the soil than a crop of corn or oats; but since this plant is subject to many diseases of soil origin, it is best to rotate crops and not plant flax oftener than once in three to five years. However, new strains of flax have been developed which are disease resistant and have a higher fiber content.

The fiber flax plant, which generally consists of one straight slender stalk with few branches, grows to a height of three to four feet. (See page 314.) There is no fiber in the roots.

There is but one species of flax plant known and cultivated which yields a fiber varying from a coarse to an extremely fine texture and suitable for weaving purposes. Of this species, two main varieties are grown for fiber production; these are the blue flower and the white flower. The blue flower produces a fine fiber of excellent quality. The white flower produces a stronger, coarser fiber of inferior quality.¹

¹ Colonel W. B. Bartram, "Flax Fibre in Oregon," *The Oregon Magazine*, Vol. 26, No. 1 (1931), p. 17.



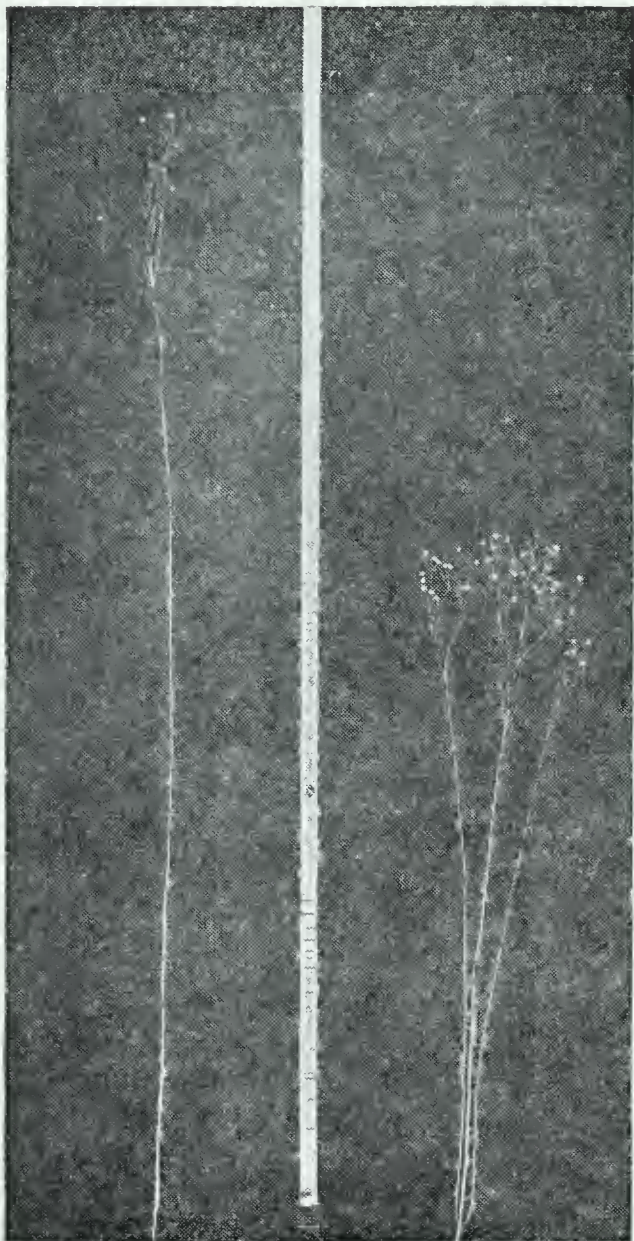
Courtesy Bureau of Plant Industry, U. S. D. A.

Flax field in flower.

The plant grown for fiber has few seed pods compared with the plant cultivated for seed. (See page 314.)

The quality of the flax straw is determined largely by climatic and soil conditions. High-quality fiber is obtained from tall, medium-sized stems. Fine-stemmed plants with poor quality fiber often result from dry hot weather during growth. The flax field is usually weeded by hand. To obtain the best quality of fiber, flax should be harvested just before the seed is mature. A slightly higher yield of fiber may be obtained and the seed is of greater value if the flax is permitted to mature before harvesting. However, the fiber loses its silky feel and luster. It also becomes more difficult to remove from the stem. Fiber obtained from overripe flax is suitable for use only in coarse fabrics.

The plant is often pulled by hand, but this hand pulling has been replaced to some extent by machine pulling. Flax is sometimes cut, but the cut ends may absorb color from the ground while drying and result in an inferior, stained fiber.



Courtesy Bureau of Plant Industry, U. S. D. A.

Comparison of fiber flax and seed flax.

The grower receives from \$5.00 to \$10.00 more per ton for pulled than for cut flax.¹

Pulling machines that successfully handle the flax are now available. These may be adjusted to the height of the plants to be pulled; also the tension with which the stems are gripped may be adjusted to prevent the injury of delicate plants. (See page 316.) The plant is lifted into an upright position, gripped above the height of most weeds, gently lifted out of the ground, and placed in bundles with the root ends even.

A self-rake reaper cuts the flax close to the ground and places the straw on the ground in rows. If the flax plant is pulled, it is usually tied in small bundles and left on the ground to dry for a few days. (See page 315.)

Rippling. Rippling, the next process in the preparation of the fiber, is the removing of the seeds from the stems. A method must be employed that will strip off the leaves and seed bolls without breaking or injuring the straw. This is often done by passing the head of the plant through a coarse comb or between two wide pulleys held together by springs. Machines are in use that whip or thresh the seed from the straw. After the seeds have been removed, the straw is again

¹ Frank C. Miles, "Fiber Flax," U. S. Department of Agriculture, Farmers' Bulletin No. 669, p. 9.



Courtesy *Consumer's Guide*, U. S. D. A.

Extreme care has to be exercised in drying flax. The bundles have to be turned several times in order to expose the interior to the sun and air.

Flax is tied in bundles and placed in small stacks to cure if it is to be retted.

Retting. The removal of the fibers from the stem of the flax plant is done by retting, in which the connective tissue is destroyed by bacterial action, or by decortication in which the green stalk is beaten to loosen the connective tissue. If retting is used it is the most important phase of preparation. Only an experienced person can carry out this process. Flax fiber that is over-retted will be weak, and flax that is not sufficiently retted will be difficult to separate without injuring the fibers. The two principal methods of retting are dew retting and water retting.

Dew retting has been employed in many countries from earliest times and is used to a limited extent today in certain parts of the world. This consists of spreading the flax straw in a thin layer on the grass and leaving it exposed to the action of the weather for several weeks, usually from four to eight. Moisture, which is essential to the process of fermentation, may have to be supplied by artificial means. More even action



Courtesy Drake Bros. Studio

Pulling machine at work in a flax field.

is obtained if the straw is turned during the retting. After retting is complete, the straw is raked up and again stacked to dry. Dew retting is an inexpensive process but the fiber is uneven in color and quality. This method is adapted to individual farmers or small plants and usually handles only poorer quality fibers.

Water retting may be done in stagnant or running water. (See page 317.) For this method the straw is usually stacked in crates, but may be placed in sacks which are immersed in water. The straw is stood on end to prevent dirt and sediment from settling on it, causing discoloration of the fiber. Slowly running water is preferable, as swiftly running water carries away the bacteria and thus prevents or retards fermentation. It is important also that the water be free from minerals. The crates of flax straw are submerged a few inches below the surface of the water and anchored in place. It is necessary to add extra weight as the fermentation develops, for the formation of gas causes the crates to rise. This is one method of determining how the retting is progressing. As the fermentation



Courtesy Keystone View Co.

Flax retting scene. Crates covered with straw and weighted down with stones; bundles of straw ready to be placed in the crates.

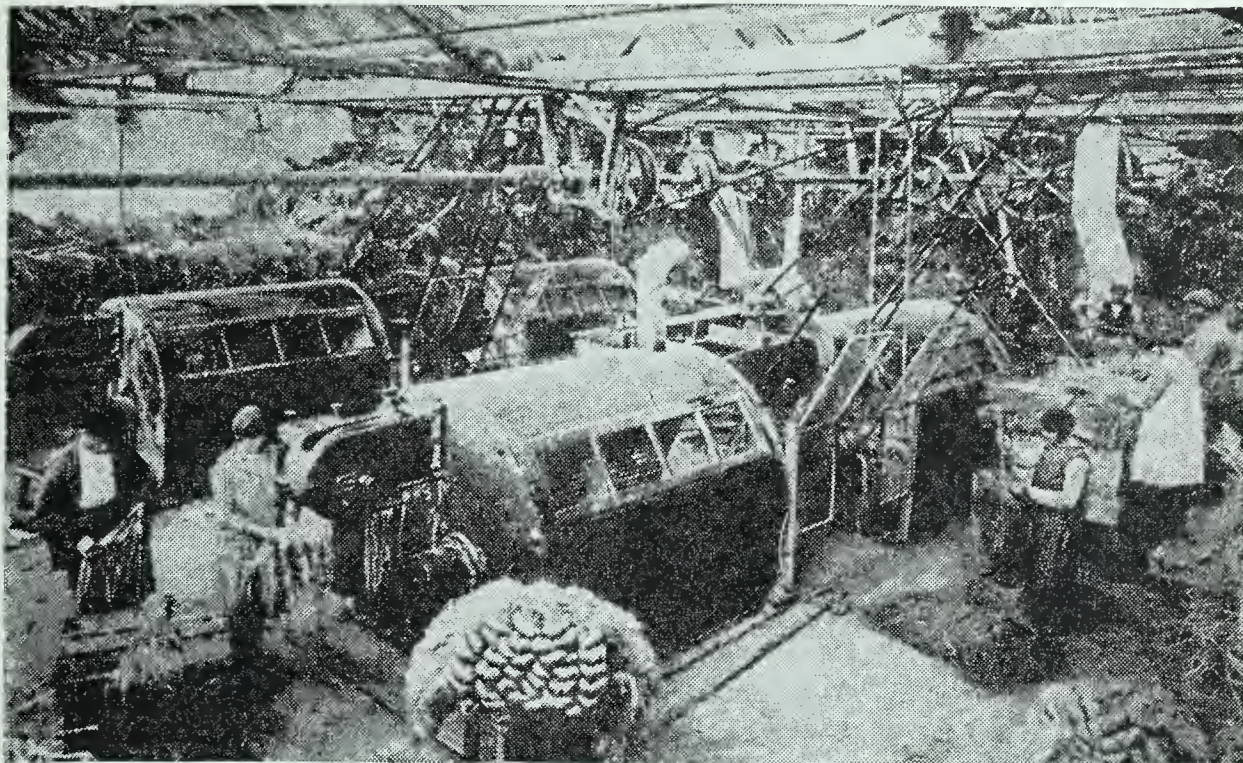
progresses, the fibers must be closely watched to prevent over-retting. When sufficiently retted the straw is soft and covered with a green slime, and when bent the woody portion will spring out of the stalk. When the process is completed the flax is removed from the crates and stood up to drain and dry. In some countries the straw is removed from the crates during the process of retting, dried for a few days, and returned to the crates. This interruption is said to destroy certain microbes and results in a stronger fiber. Running-water retting produces a good fiber, even in quality and of a pale yellowish-white color.

Stagnant-water retting is used in some countries. In this method the flax is placed in ponds of water. Formerly some provision had to be made to remove the water and replace it with fresh water as needed. Recently, research has revealed a

method of aerating the water which has practically eliminated the problem of emptying the retting tanks. Water in which flax has been retted is not poisonous but is devoid of oxygen and cannot be used by animals. In pools of stagnant water the decomposition progresses so rapidly that there is great danger of over-retting. Toward the end of the treatment the flax must be watched constantly. In some places the flax is removed from the pool before retting has been completed and is spread on the grass to finish. In this method as well as in the others the retted straw must be drained and dried.

The time required for retting depends greatly upon the temperature of the water. In warm climates it may require only ten days to two weeks, and in a cooler climate from two weeks to four weeks may be needed. Much experimental work has been done in order to reduce the time and cost of retting and to improve the product. The use of tanks of warm water has speeded up the time and eliminated many of the unpleasant features of retting without reducing the quality of the fiber. (See page 324.) The use of chemicals in the retting tanks may be considered to be still in the experimental stage, although processes have been developed by which it is claimed that flax can be produced which will permit it to compete with cotton at ten cents per pound.

Storing, breaking, and scutching. The retted straw may be stored any length of time after it is dried. The remaining processes consist of removing the dried bark and pith and separating the bundles of fiber which lie just under the bark of the stem. This is done by breaking and scutching. Originally these were altogether hand processes; today they may be done entirely by automatic machinery. (See page 319.) Breaking consists of reducing the stem of the plant to small pieces. Scutching is the removing of these broken pieces of stem and the beginning of the cleaning of the bundles of fibers. A flax brake may consist of an apparatus which is simply an aid to hand operations, or it may consist of a series of fluted iron rollers that largely perform the operation of breaking. The dry, retted flax is fed endwise through these rollers. The short, broken pieces of bark and stem produced by breaking are



Courtesy *Consumer's Guide*, U. S. D. A.

The turbine scutching machine has replaced much hand labor in the processing of flax.

known as shives. These are removed by scutching, which may consist of beating the flax against stakes. Scutching machines are in use in which the flax is presented to a series of revolving wooden beaters that strike and clean the fiber. It is necessary with this type of apparatus for the workmen to hold the flax while it is scutched and to present first one end and then the other end of a bundle of straw to the beaters.

Decortication: the processing of green flax. For several years much experimental work has been done on a method of processing the green flax straw, directed toward eliminating the slow and expensive process of retting. This method is spoken of as decortication and consists of breaking the unretted stem so as to remove the fiber without injuring it. The materials closely associated with the fibers cannot be removed from the green straw without severe mechanical beating. Therefore, it is considered necessary to ret or chemically treat the decorticated straw to remove the gum that has not been destroyed. However, some authorities claim that decortication prior to retting eliminates at least 80 per cent of the work. It



Courtesy Colonel W. B. Bartram

View showing part of the flax fiber dressing and grading room.

is necessary to dry the decorticated fiber artificially, as it cannot be stacked to dry. A new method of drying the flax by means of a heat drier so constructed as to burn the waste from the factory has reduced the cost of drying by one-half. The processing of green straw has been developed in many localities, especially in the United States where it is being used successfully with fiber flax and in the utilization of the fibers from flax grown for seed.

One system of decortication includes only breaking the green straw and scutching it. The other system includes these two processes and hackling also and results in long fibers. However, it is a more expensive system and has a low rate of production.

The decortication of unretted flax requires fewer operations than are required in the handling of retted flax. Therefore, the processing plant is less elaborate and can be built at lower cost. Many factories of this type include in their opera-

tions the growing and harvesting of large areas of flax. In the contract system which is in general use, the factory owners supply the seed and closely supervise the sowing and handling of the crop. The pulling machines are generally owned by the factory. One mechanical puller can handle approximately 125 acres of crop during the season; hence, eight machines are required for each 1,000 acres.

The men attached to each machine usually include a tractor driver, pulling machine attendant, and four or five men to pull the straw in the corners and other places missed by the machine and to stack the bound bundles thrown out by the machine.

A comparison of the cost of harvesting by the different methods is shown by the fact that at one time hand pulling cost \$12.00 per acre; machine pulling \$8.00 to \$10.00 per acre; and a self-rake reaper from \$.50 to \$1.00 per acre. When there is a scarcity of labor these differences between methods are greater.

Classification of linen fibers. The long fibers from which part of the shives have been removed are known as line fibers; the short, broken fibers are known as tow. Tow fibers, removed during the process of scutching, are known as scutching tow. The cleaned fibers are roughly sorted into bundles of even length, then tied and baled. These bales, weighing from 200 to 224 pounds, are now ready for the spinning mills.

PROBLEM 2. HOW DOES THE GEOGRAPHIC SOURCE INFLUENCE THE QUALITY OF THE LINEN PRODUCED?

Certain definite characteristics pertain to the flax produced in various countries, because of the differences in the climate, soil conditions, methods of cultivation, harvesting, and retting practiced in these places.

The United States offers the best market in the world for linen goods, importing more than \$20,000,000 worth of fabric and large quantities of fiber each year; yet its contribution to the total world production of approximately 1,900,000,000 pounds of flax fiber is negligible. There are certain limited

areas in the northern part of the United States where the climate and rainfall are favorable to the production of the fiber flax; but reports indicate that there are comparatively few acres sown to it, while more than 3,000,000 acres are sown to seed flax. What reason can you suggest for this?

The production of flax for seed has been developed in the United States because this type of flax does not require as careful preparation of the soil nor as painstaking attention during growth. Recent development of automatic machinery and the use of methods that eliminate disagreeable work and expensive hand methods are permitting the production of fiber flax in this country.

Progress in these lines is particularly noticeable in the Pacific Northwest. It is stated by a reliable authority:

During the past fifteen years methods used in the processing of fiber flax in Oregon have undergone a complete transformation by the introduction of the most successful inventions in flax machinery. These advancements have placed fiber flax in a position to offer possibilities of becoming a permanent paying crop for the Oregon farmer.¹

A definite effort is being made by the state of Oregon to maintain the high quality of the seed and to increase the yield per acre. The farmer usually works on the contract plan, whereby the flax company agrees to furnish clean seed and to purchase the straw if it complies with certain requirements of quality. The land is inspected and approved before planting, and the crop is inspected before harvest and graded for quality. The farmer agrees to pay for the seed when his crop is marketed. He also agrees to plant on only approved soil and before a definite date. This is most important as it is necessary to plant early in order to obtain the benefit of spring rains. Early planting also insures time for growth before the hot, dry period starts. Early-sown flax produces a higher percentage of fiber than flax sown later.

¹ Brittain B. Robinson, *Fiber Flax in Oregon Division of Cotton and Other Fiber Crops and Diseases*, U. S. Department of Agriculture, Bureau of Plant Industry.

The farmers are paid for their straw by weight, after deduction has been made for weeds. The same is true of the seeds, as the farmer is paid on the basis of the percentage of flax seeds present. Oregon has the advantage of perfect harvesting conditions. There is no danger of rains that would prevent machine pulling because of softened ground. The dry weather insures correct curing of the straw and also the maturing of the seed. The long, dry summer is an advantage in retting, as it permits the drying of the retted straw in the sunshine.

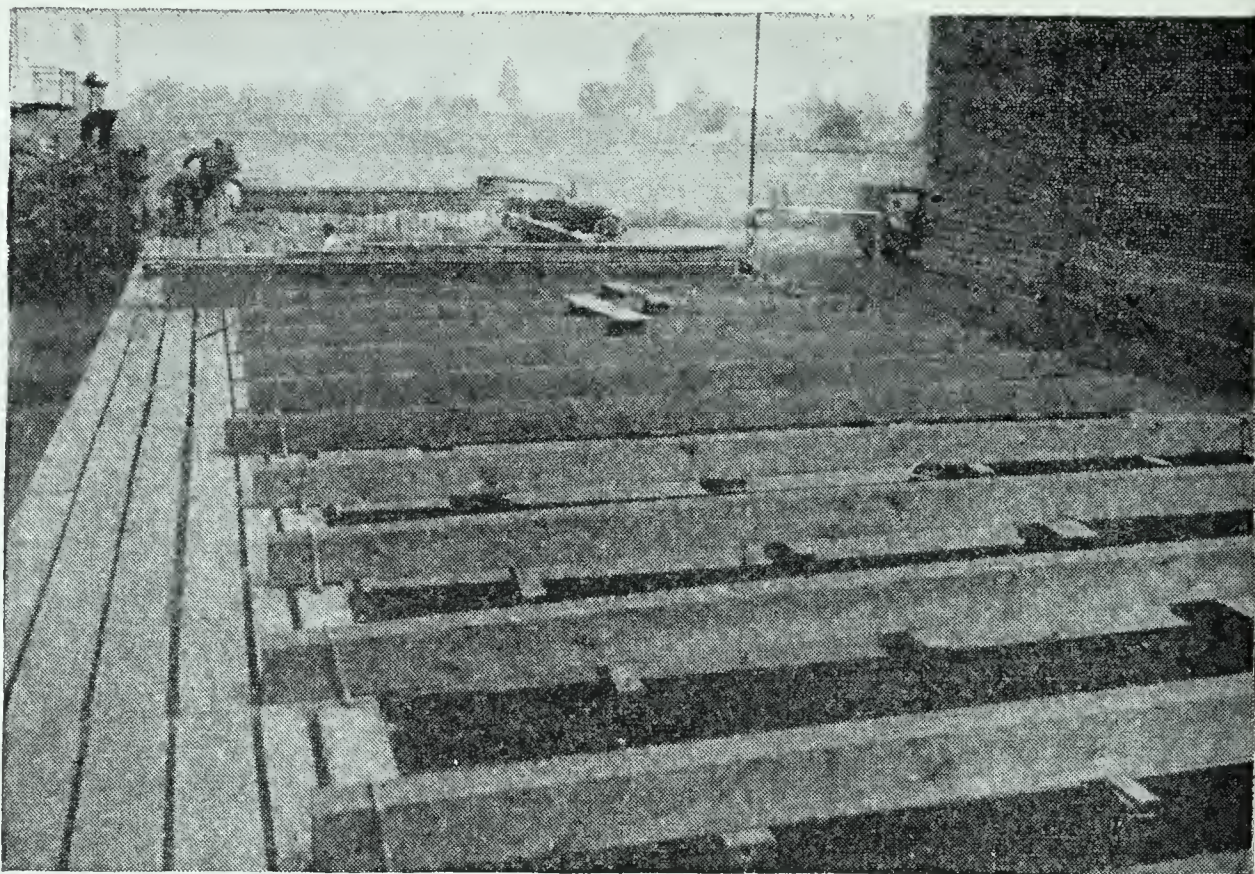
The first flax-pulling machine came to Oregon from Canada in 1923. For several years flax-pulling machines were brought in from Canada, but in 1927 the state of Oregon began building its own flax-pulling machines at a saving of \$1,000 each.

The tank method of retting as carried on in Oregon has proved highly successful and is being copied in other parts of the world. (See page 324.) The retting tanks are 7 feet deep with a capacity of 13 tons each. The tanks are filled with flax straw standing on end in two tiers. A gate holds the straw down. After the straw is in place, the tank is filled with soft water. A temperature not to exceed 84° F. is maintained by means of live steam. One foot of water is run off from the tanks each morning and is replaced with fresh water. This method reduces the acidity of the water in the tanks, and to a great extent controls the offensive odor which accompanies the fermentation. An expert determines when the retting is completed. The water is then drained off, the flax is removed, and the tanks are thoroughly cleaned. The retted straw is placed in the field to dry. For drying it is stacked in wigwam form. After drying it is tied in bundles and stored to cure.

The retted straw is fed into machines that break the woody part of the straw, after which it is handled in an all-through scutching machine.

The cleaned, straight fibers free from shives are taken to the grading and dressing department where they are prepared for shipment to the mills. (See the illustration on page 320.)

The production of fiber from seed flax. The destruction, usually by burning of the straw of the seed-flax plant, has



Courtesy State Flax Industry, Salem, Oregon

View of retting tanks at Oregon State Prison. The retting plant consists of 25 tanks with a retting capacity of about 300 tons to a batch. The flax is being placed in the farthest tank.

been designated as America's most valuable agricultural waste. The normal acreage of flax seed is approximately three and one-half million acres, Minnesota being the principal state raising the flax. The crop is grown as any cereal crop. The straw cannot be permitted to remain on the ground to rot because of the pectin matter which serves to cement the fibers to the other parts of the plant. The action of dew and rain on the straw would tend to free pectic acid which would sour the land. Hence the straw has been burned. During the war the acreage of seed flax increased until it had reached six million acres in 1943. As the average straw waste per acre is one ton and the fiber content is about 20 per cent of the straw, the fiber content of the seed flax harvested in 1943 was approximately 1,200,000 tons. Much of this was wasted.

Experiments were started in the early 1930's to salvage this waste. It was found that most of the varieties of seed flax produced in the tropical and sub-tropical areas of the United

States did not yield a fiber suitable for any type of textile; but that certain types grown from seeds from northern latitudes produce fibers that can be used for textiles, especially in the heavier yarns and fabrics. The fibers were removed from the green straw by decortication. These fibers were then degummed by a chemical process and finally the total elimination of the shives was accomplished mechanically. Some mechanical changes were required to adapt the existing machinery in order to spin this rough green fiber.

Extensive research, conducted at the University of Minnesota on the use of these raw fibers in the production of coarse linens, has resulted in the issuing of licenses to interested firms for the use of their patented process.

Other sources. The quality of flax grown in Oregon and other parts of the United States is equal to that produced in any other part of the world. At present, however, the United States, like England and Scotland, depends chiefly on the imported fiber for its mills. Ireland, too, with nearly one million spindles operating, finds it necessary to import more than three-fourths of the fiber used. The countries that supply the flax fiber in the order of amounts produced are Soviet Union, North Ireland, Germany, Great Britain, Lithuania, France, Estonia, United States, and Italy.¹

The flax produced in Belgium is noted for its color, strength, and fineness. In its natural state this fiber is yellow or yellow-brown, the lighter shades usually indicating fine quality, and it has a firm feel. The high quality of this fiber is used as a basis for comparison of the qualities of fibers produced in other localities. The region around Courtrai has been devoted entirely to flax culture, because the soft, slowly running water of the river Lys furnishes highly satisfactory conditions for retting. Canals leading into and out of Courtrai furnish a method by which the farmers can transport large barges of flax to be retted or to be returned to the farms. Only the best selected seeds are used here, and great care is given to the growing of the flax and to the proper retting of the fiber. The straw is placed erect in crates lined with bur-

¹ Agricultural Statistics, U.S.D.A., p. 126, 1944.

lap to keep out the dirt. After fermentation has started, the crates are raised and the flax inspected. If the fermentation is developing too rapidly the bundles are taken out and allowed to dry, after which they are replaced in the crates. If the retting is progressing satisfactorily the bundles are turned and placed back in the water. Near the end of the process the flax is watched constantly, even through the night, so that removal may be made at exactly the correct time. This careful attention is rewarded with the production of a high-quality fiber.

Those engaged in the handling of flax have a full-time occupation, since when the retting season is over the scutching begins and thus the cycle continues. The handling of the fiber by experts only, accounts in part for the superior qualities of Belgian linen. Even in Belgium running-water retting has been replaced by tank retting similar to the process used in Oregon.

Ireland ranks first in linen manufacture, operating nearly a million spindles. Irish linens are among the best made, although only a small percentage of the world production of raw flax is grown in Ireland. Irish flax is probably the strongest flax produced in any country. However, it cannot be spun into such fine yarns as some other types but is especially suited for the manufacture of linen thread. These yarns are a dark gray color in their raw state. Most of the linen fabrics and yarns that come from Ireland are not made of domestic flax as only a small percentage of the amount consumed in the industries is produced at home. The United States takes practically one-half of the piece goods and more than three-fourths of the damask table linen exported by Ireland.

The Soviet Union is the most important flax-producing country. Of the world production of 1,900,000,000 pounds, the Soviet Union produces 1,410,944,000 pounds.

Fiber produced in Russia is suitable for the manufacture of medium and coarse yarns. Both water retting and dew retting are employed. The color of the Russian flax is a dark gray similar to Irish flax; however, the fibers have a softer feel and a much lower breaking strength than that grown in Ireland. One-third or more of the product comes to the United States.

France ranks second in output but imports four-fifths of its linen fiber. French linens are among the best made.

Germany produces some high-grade linen fabrics, but many of the German linens found in the United States are medium or coarse cloths.

Scotch linen is often sun- and grass-bleached and has a reputation for being of high quality. Some of the heaviest grades of canvas, tarpaulin, and oilcloth are produced in Scotland.

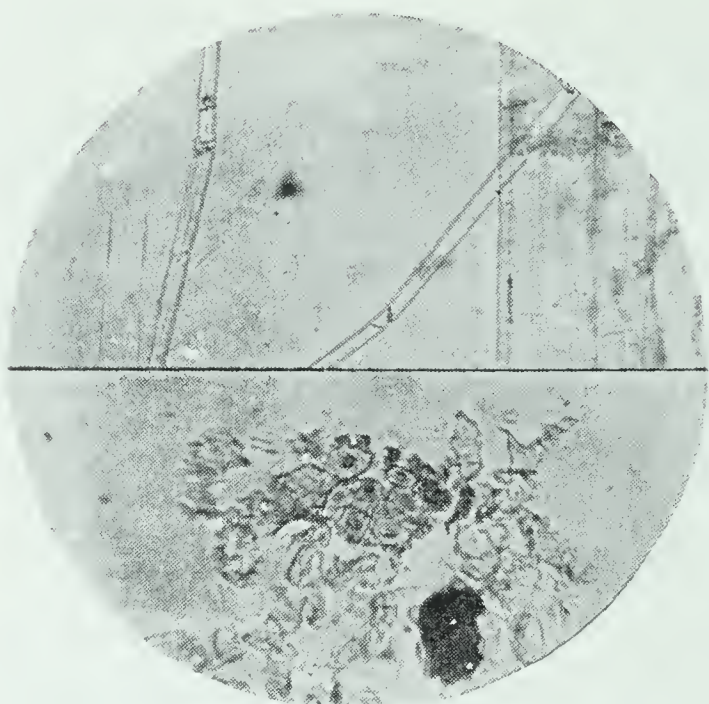
At one time the snowdrop or shamrock patterns were characteristic of Ireland, and the check was used exclusively by Germany. This is no longer true, as various countries weave linens of many patterns.

The flax-spinning mills in the United States are located in Massachusetts, New York, New Jersey, and Oregon. Here linen is spun for use as sewing thread, shoe thread, harness thread, fish lines, fish nets, and twines. Mills are being built in Oregon and other states for the processing of linen yarn and the weaving of linen fabrics of different types.

PROBLEM 3. WHAT ARE THE MICROSCOPIC AND PHYSICAL PROPERTIES OF THE LINEN FIBER?

The linen fiber is one of the strongest of our fine vegetable fibers. The individual cells or filaments are only 25 to 30 millimeters in length and microscopic in diameter. They are rather cylindrical in shape but polygonal in cross section, and taper to a point at each end. (See page 328.) These individual fibers have a thick cell wall with central canal or lumen so narrow as to be scarcely visible under ordinary magnification. The linen fiber is characterized by peculiar markings known as "nodes" which are caused by the irregular growth of the stem. These markings are visible under the microscope and serve as a means of identifying the flax fiber. Unlike the other natural fibers, the bundles of fibers are never separated to the individual filaments but are left more or less cemented together in groups. These bundles or groups of fibers are the commercial or raw linen fibers.

The natural color of linen fiber varies from cream-white to



Photomicrograph by Schwarz

Longitudinal and cross sections of linen fiber.

gray, depending upon the method used in retting. Bleached, good-quality linen is snow-white. Bleaching weakens the fiber by tending to separate it into its individual filaments. Therefore linen is sometimes used in the unbleached, half-bleached, and quarter-bleached conditions.

The hygroscopic qualities of the vegetable fibers vary but little. The allowable regain of eight

per cent for linen is slightly more than that permitted for cotton. Moisture seems to spread through the meshes of linen fabric more readily than through cotton fabric, though it does not penetrate the fiber and therefore evaporates quickly from its surface. This accounts for the rapidity with which linen fabrics give up their moisture. This characteristic and the high absorptive quality make linen the most valuable fiber for use as toweling, handkerchiefs, and wash cloths. Its desirability is further enhanced by the fact that linen fabrics do not shed lint readily.

The comparatively smooth, sleek surface of the linen fiber causes it to give up soil easily. Linen is considered by some the most hygienic fabric, because bacteria seem to increase slowly on it, dirt is easily removed by laundering, and the cloth leaves no lint. It cannot be boiled, however, without slight injury. Fine linen has a luster almost equal to that of silk, is tenacious, and will endure hard wear. Because linen possesses these properties it is the best fabric for table use. Its wide use for this purpose has resulted in all table fabrics being spoken of as table linen.

Pure flax and cotton approximate the same chemical com-



Courtesy Bureau of Plant Industry, U. S. D. A.

Flax hackles through which scutched flax is drawn by hand, combing tow out of clean, straight flax fiber.

position and chemical properties. The bundles of individual linen fibers more or less cemented together by the intercellular tissue, as used in commerce, contain about 5 per cent less cellulose than cotton. The impurities consist of pectin matters and wax, an essential part of the fiber. Linen is more easily injured by high temperatures and hot water than cotton. For this reason it should not be boiled, and care should be used in ironing to prevent scorching.

Linen is slightly more resistant to the action of acids and more easily attacked by alkalies than is cotton. Towards mordants and dyestuffs, linen does not react so readily as cotton; hence its manipulation in dyeing is more difficult. In general, however, it may be said that the dyeing and treatment of linen and cotton are practically the same. Linen does not take or hold the dye well; therefore it is more likely to be found in the various bleaches than in color. Dress linens are dyed in many colors, some of which are not always satisfactory.

The following tables show the superior strength of the flax fiber.¹

FIBER DIMENSIONS

ULTIMATE FIBERS	FLAX	JUTE	COTTON
Range of lengths (mm.)	8-69	1-6	10-50
Mean length (mm.)	32	2.5	25
Fineness (grams per kilometre)	0.19	0.17	0.19

FIBER STRENGTHS

FIBERS	BREAKING LENGTH, KILOMETRES	FLAX: 100
Flax	59	100
Hemp	54	91
Ramie	51	86
Silk	38	64
Jute	34	58
Cotton	33	57
Wool	12	21
Nylon	44	75
Acetate Rayon	12	21

The marked difference in the cost of linen and cotton has led to the development of processes that enable cotton fabrics to simulate linen. There are urgent requests for physical tests that will make the identification of linen possible. Of the tests advocated for this purpose, perhaps the tearing test is most commonly accepted, though not reliable. Linen, when torn, shows ends unequal in length and glossy with the fibers paralleled, contrasting with the almost even, curling, lusterless yarns of untreated cotton. Today, however, cotton may be so treated as to render this test invalid. Hemp, also, cannot be detected by this test.

The untwisting test is often used. Linen yarns when un-

¹ A. J. Turner, M.S.D. Sec., "Flax Utilisation," *Textile Recorder*, Vol. 65, May, 1947, p. 53.

twisted show a more or less parallel arrangement of glossy individual fibers which contrast sharply with the raveled cotton yarns that show numbers of fibers in each turn of the yarn. A third test often advocated is the singeing test. Linen yarns when scorched will show compact ends burned in an even manner, and cotton yarns similarly tested appear brushlike, with much more spread.

The ink test and the oil test are also used. Ink or oil dropped onto linen will follow along the yarns, but on cotton it spreads out into a circle.

These tests have significance only as long as developments in the textile industry do not lead to processes that mask the results or cause changes in other fibers that may invalidate these findings.

PROBLEM 4. HOW IS LINEN FABRIC MANUFACTURED AND FINISHED?

The manufacture of the scutched fibers into linen fabrics and articles for use is carried on in three separate institutions. Yarn is manufactured in the mill; cloth is produced from this yarn in the factory; making up into articles such as towels and table linens, and embroidering are done in the warehouse.

Yarn. Manufacturing operations in the flax mills are carried on in several rooms, in each of which various processes may be conducted. In the hackling room the scutched fibers are further cleaned and made into a continuous strand or sliver. Hand hackling or heckling was one of the most arduous processes in the handling of flax fiber. (See page 329.) It consisted of drawing first one end and then the other of the flax through a succession of combs. The number of combs and the degree of fineness of the last combs determined the fineness of the yarn to be made. Today, hackling machines take the roughed or scutched flax, clean, straighten, and comb the fibers, and deliver them in the form of a sliver ready for the drawing frames.

Many of the production and preparation processes have been studied with the idea of reducing the cost or shortening

the time of preparation. One system that has been patented prepares the flax for weaving without the use of the hackling machine. A substitute in the form of a combined drawing and combing machine claims to reduce production cost by eliminating the formation of tow in the process.¹ The drawing frames are used, as in the manufacture of other yarn, to parallelize the fibers further and to equalize the strand and reduce it to the desired size. From these machines the roving is taken to the spinning frame.

So far we have followed only the course of the long, fine fibers which are made into line yarns. We must go back and consider the short fibers, or tow, that have been removed from the line by every step in the processing. The first tow was obtained when the retted straw was scutched to remove the shives. This is dirty, coarse, and short. It is, however, of commercial value for the making of coarse yarns. All subsequent processes of hackling, roving, and spinning produce their type of tow, which improves in quality and contains less dirt as the work proceeds.

Tow fibers, which may be coarse, short, and tangled, are separated, cleaned, and formed into a sliver on a carding machine. Coarse, cheap flax may be first opened on the breaker and combined with tow in the process of carding. Tow slivers may be combed after carding. In the combing, the slivers are separated into tufts and the tufts are overlapped into a continuous strand. These are doubled and drawn and formed into roving to be spun in the same manner as line fibers are handled.

Flax yarns are classified according to the class of fibers from which they are manufactured as "line" yarns and "tow" yarns. Line yarns are made from the long combed or dressed fibers and may be of any size or quality. Tow yarns are made from the broken and short fibers that are removed from the line fibers during hackling and other processes.

Flax yarns are classified according to the purpose for which they are to be used as warp, weft, and thread yarns. The warp

¹S. A. G. Caldwell, "Can Flax Hackling Be Dispensed With?" *Textile Manufacturer*, Vol. 66, No. 781 (April, 1940), p. 150.

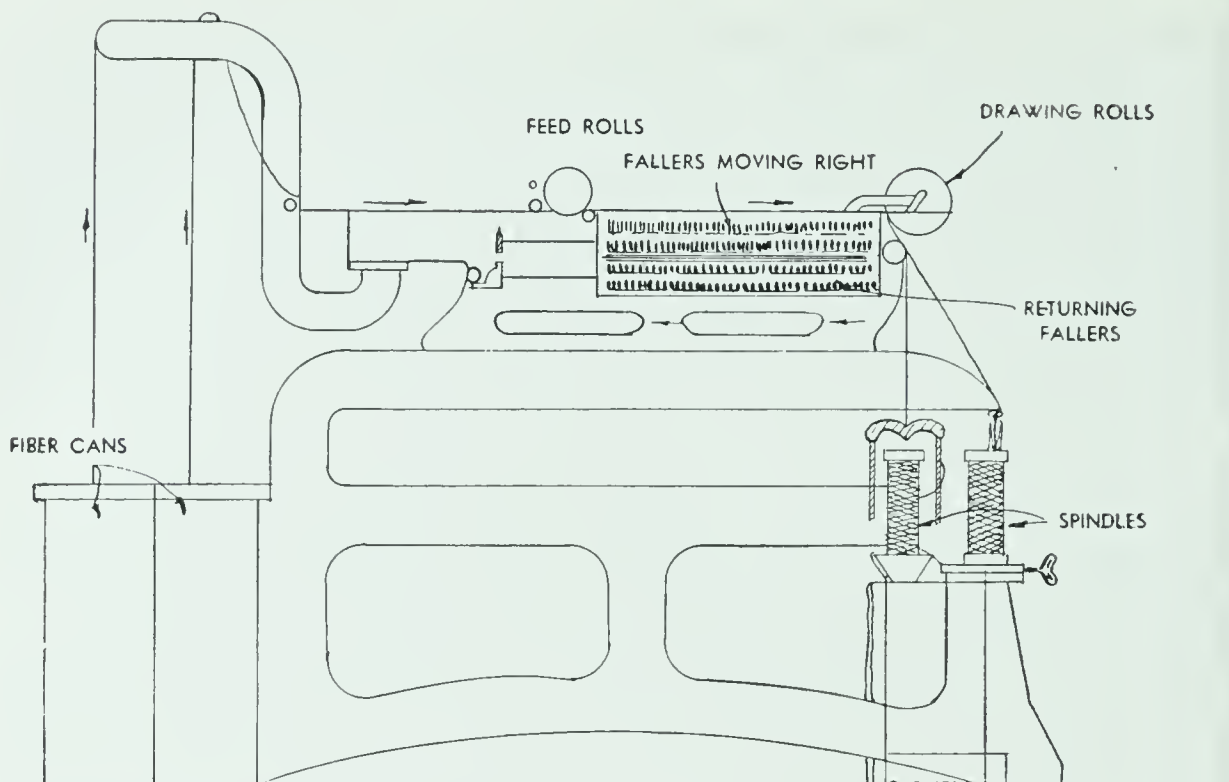
yarns must be strong and without protruding ends if they are to withstand the strain placed upon them during weaving. This is especially true of flax yarns, as they are low in elasticity. Therefore, the warp yarns must be made from high-quality, strong fibers. Weft yarns usually contain less twist and hence are softer and give a fuller appearance to the cloth. In the manufacture of thread only strong yarns can be used, as strength is an essential quality.

In the spinning of flax yarns three distinct methods are in use—wet, gill, and dry—each of which imparts definite characteristics to the yarn. Of these, wet spinning is most generally used and is the only method by which fine yarns can be produced. In wet spinning the rove is passed through a trough of hot water, thus softening the gum. This loosening of the fibers permits them to be drawn out into the desired count. Yarns spun by this method are characterized by their smooth surfaces; hence, this method is especially suited to the spinning of warp yarns.

Gill spinning is a type of wet spinning in which the fibers are further controlled during drafting. (See page 334.) In the gill box, comb teeth are so placed that they are drawn through the material as it passes along the drawing frame. The process is comparable to the combing of one's hair. This combing of the fibers aids in the paralleling action and produces a yarn with great levelness. The gill box is used in the spinning of all types of long fibers, such as wool tops, flax, and jute.

Only coarse yarns are spun by the ordinary dry method. These yarns are not strong and are uneven and rough in appearance. Flax yarn may be doubled and twisted into thread for sewing and lace-making. Flax yarn to be made into thread must be boiled to bleach and soften it. Jacquard loom cords and the better grade of sash cords are made of linen.

The method of numbering linen yarns in England and America is by the number of cuts in a pound. A cut consists of 300 yards. A number 1 or 1^s linen yarn would be a yarn that requires 300 yards to weigh one pound. A 2^s would require 600 yards to weigh one pound. Hand-spun thread for the fine laces may be as high as 400^s.



Lengthwise section of a flax gill box.

Linen fabrics. The greater part of linen fabrics are woven. Lace is probably the one exception to this. The yarns may be wholly or partly bleached or they may be woven in the unbleached condition. Linen warp yarns are sized in the slasher before being drawn into the loom. A moist atmosphere is essential for the weaving of linen cloth.

Bleaching linen. The treatment for bleaching linen is, in general, the same as for all bleached fabrics, the chief difference being in the degree to which the bleaching action is carried out. It is generally done by commercial bleachers on consignment from the manufacturer. Linen that is to be bleached must be treated first to remove all the wax and foreign matter. This is done with slaked lime, soda ash, or caustic soda. A bleaching powder solution supplies the necessary oxygen to oxidize the coloring matter, and an acid is used to remove the bleaching powder.

The best-quality, high-grade linen fabrics may be bleached by being well moistened and laid on the grass; remoistened and returned to the grass; and so on until the desired amount of whiteness is obtained. Loss may be caused by field mice and by stones that result in damage to the fabric and to the ma-

chinery. Chemical bleaching requires about six days. Dew bleaching combined with some chemical bleaching requires much more time and handling, and dew bleaching unsupplemented may require many weeks. This method of bleaching was originally in general use for linen, and even today produces the best and strongest fabric.

CHARACTERISTICS OF FLAX FIBERS

Microscopic appearance . . .	Longitudinal—joints or nodes present
	Cross section—polygonal
Length	10''–40''
Diameter	14.5 microns
Color	Cream white to grey
Luster	High
Strength	6 grams per denier
Elasticity	Low
Heat conductivity	Good
Effect of heat	Resistant
Water absorbency	Low
Standard regain	8.5%
Effect of moisture	Increases strength and decreases elasticity
Effect of sunlight	Resists
Attack by mildew	Yes
Attack by moth	No
Strong acids	Destroy
Volatile organic acids	Destroy
Strong alkalies	No injurious effect

Fabrics such as sheeting, crash, and duck are constructed with the plain weave; drillings are made with a twill weave; and towels are of either twill or figure weave, usually diaper or huck design. Table linens are generally woven on the Jacquard loom. With the development of new finishes and the practice of combining two or more fibers in one cloth, dress fabrics made only of linen are sometimes difficult to obtain. Fiber content labeling would greatly assist the consumer.

Dresses, blouses, and shirts are articles of clothing for which linen may be used. For these articles the fabric may be of

plain, twill, or figure weave, or a novelty cloth. With the perfecting of noncrushable linens the style trend is toward suits and coats of this fiber.

Some of the coarse linen fabrics, such as canvas and duck, are given little finish. These fabrics are inspected and all lumps and knots are removed; they are then sheared and calendered but are rarely bleached or dyed. This is true also of some of the coarse toweling. These same preliminary processes are used on the better-quality linen fabrics to produce a clean surface on which to apply the desired finish.

Suggestion for the Laboratory

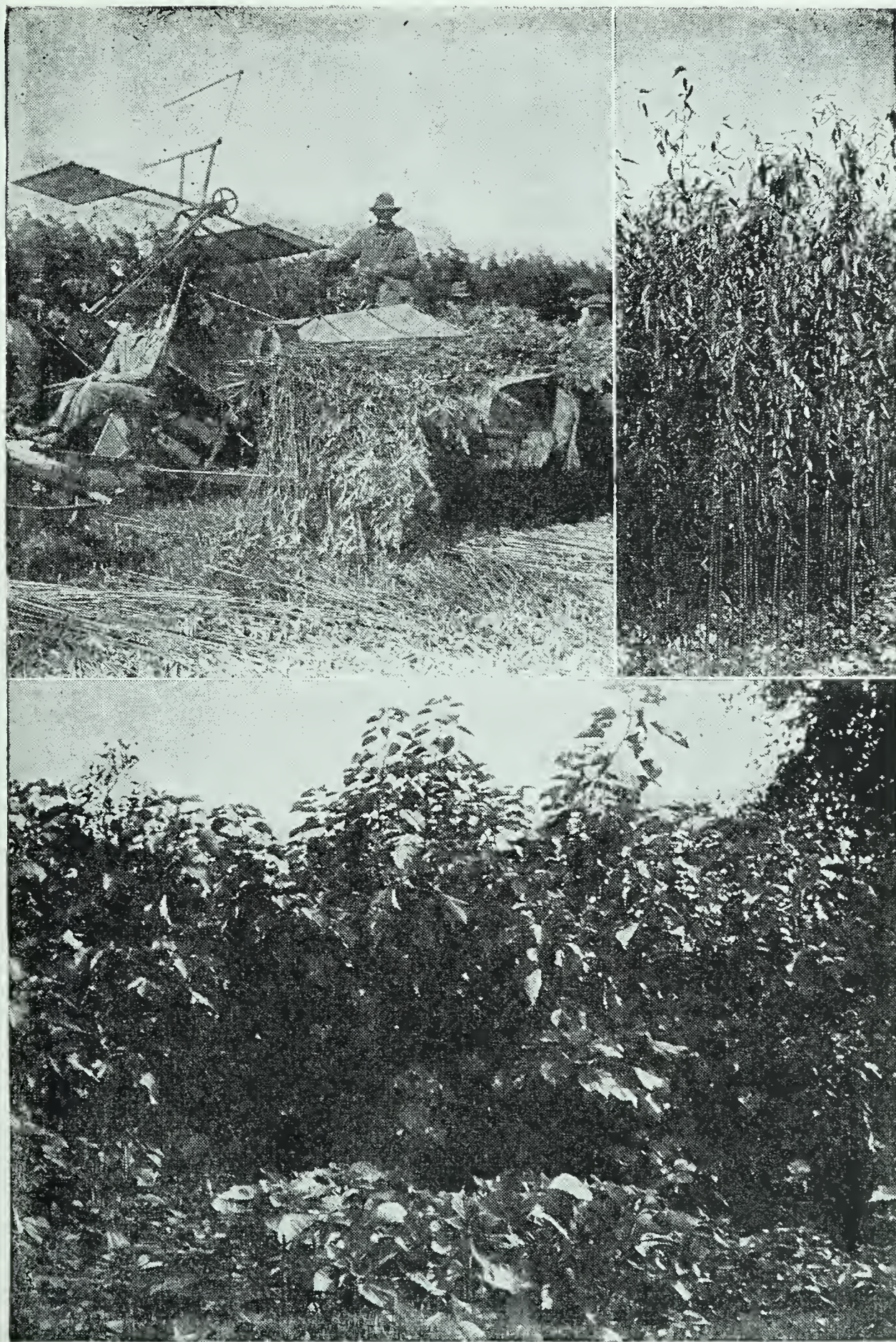
Study high power magnification of linen and other bast fibers. If time permits, make a drawing of each. Compare the physical and chemical properties of linen with those of cotton. Study available linen fabrics. Compare the prices of these fabrics with similar fabrics made of cotton or rayon. What qualities do the linen fabrics possess that the others lack?

PROBLEM 5. OF WHAT IMPORTANCE ARE OTHER VEGETABLE FIBERS?

Natural vegetable fibers of importance in the textile industry, other than cotton and flax, are jute, hemp, ramie, and pina fiber. (See page 337.) These fibers are seldom found in fabrics for use as clothing, but jute and hemp are used extensively in the construction of carpets and to less extent in fabrics for draperies and upholstery. The principal use made of ramie and pina fiber is in the production of various household fabrics, such as luncheon and table cloths, napkins, and hand towels.

Jute. The following is said of the jute fiber:

Jute is the most easily spun, cheapest, weakest, and least durable of the important textile fibers, and it is used in larger quantities than all other plant fibers combined except cotton. The annual importations into this country for the period 1925 to 1939, inclusive, averaged 54,335 long tons of long jute fibers and 13,197



Courtesy Bureau of Plant Industry, U. S. D. A.

Top left, harvesting hemp. Top right, jute plants. Bottom, ramie plants.

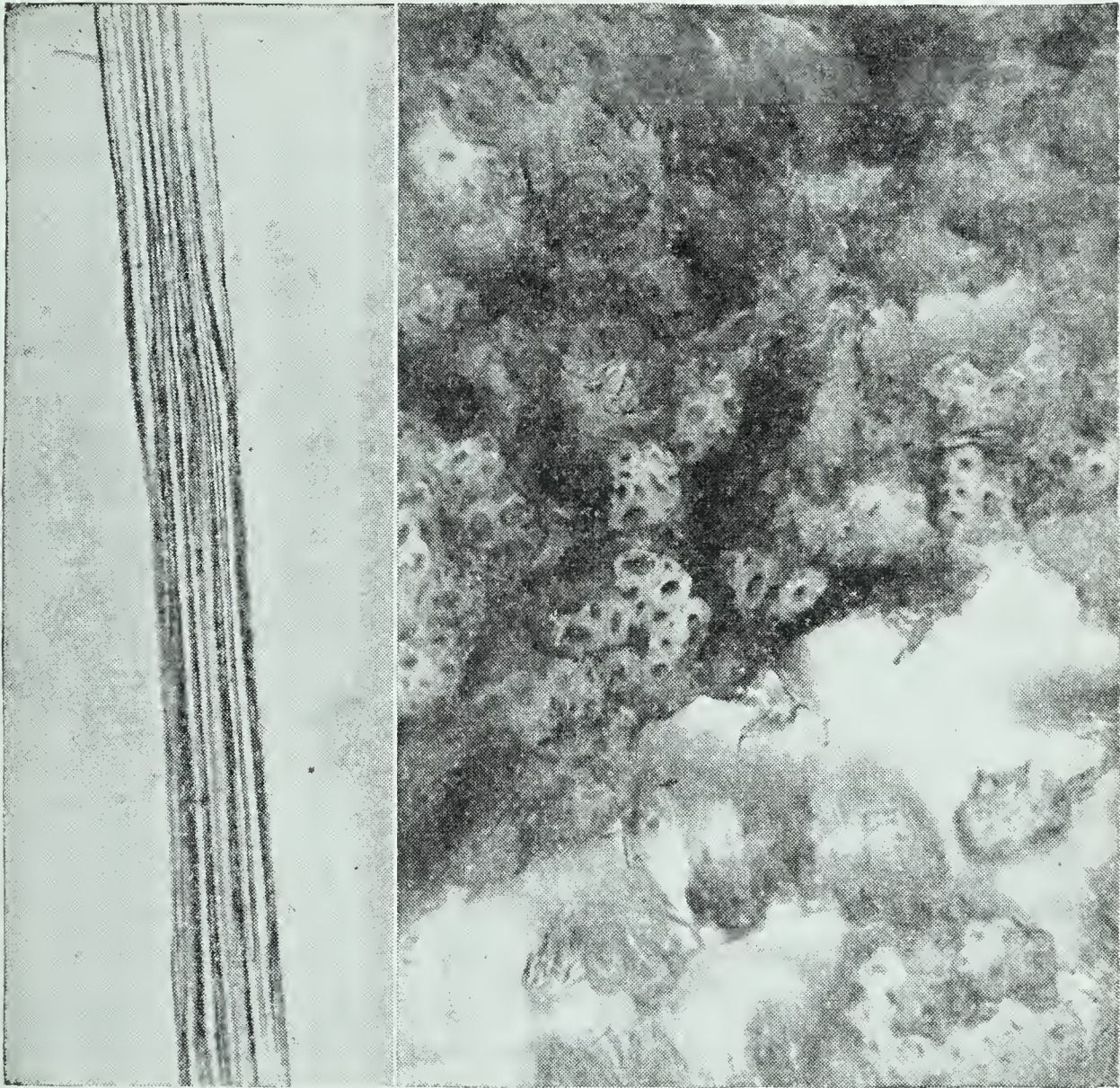
long tons of jute butts. During the same period the value of unmanufactured and manufactured fibers and jute articles imported into this country averaged \$61,642,000.¹

Practically all of the jute fiber is produced in India and 85 per cent in the province of Bengal. Here about 3,000,000 acres are devoted to the production of jute. The average yield of jute fibers is 1,200 pounds per acre, and the average price during recent years has been between six and eight cents per pound for standard grades. The ground must be thoroughly prepared—plowed two or three times or dug over by hand. Practically all of the work is done by hand. The seeds are sown by hand. When the plants are about five to ten inches high, the weeds are pulled by hand; and when the plants are in bloom they are either cut by hand or pulled up by the roots. The tops and roots are cut off and the plants are tied in bundles.

The cheapest method of removing the fibers from the jute plant is to immerse the stems in streams or pools until bacterial action destroys the tissues in which the fibers are imbedded. This treatment is known as retting. Like other processes in the handling of jute, the retting is done by the farmers and is not handled scientifically. If over-retted, the fibers are injured; if insufficiently retted, the fibers cannot be handled by the spinner.

Jute is naturally very harsh, due to a low wax content and also to its lignified nature. For this reason jute must be softened to permit the division of the fiber, and it must be lubricated. Water and oil are added to the fibers and they are passed through a series of rollers until the desired change in character is attained. Jute yarns used as warp must be sized to protect them during weaving. For this purpose a film of starch is most commonly used. The dark color of jute is difficult to remove and complete bleaching by the processes employed with other yarns would not be practical for such a cheap fiber. However, recent developments in the bleaching of jute per-

¹ L. H. Dewey and B. B. Robinson, *Jute*; U. S. Department of Agriculture, Bureau of Plant Industry.



Left, longitudinal view of jute; and right, cross section of jute.

mit the obtaining of satisfactory results with little or no loss in strength and slight loss in weight.¹

Jute dyes directly with basic dyes without any preliminary scouring or bleaching processes. Other types of dyes, such as acid, direct, sulfur, azoic, and vat, may be used with varying degrees of satisfaction. Jute is susceptible to microbiological decay, especially under conditions of high temperature and high relative humidity. Rot proofing is accomplished by the use of insoluble antiseptics which are fixed on or within the fabric. Mineral salts, organic-metallic compounds, and phe-

¹ H. D. Parsons, "The Processing of Jute," *Textile Recorder*, Vol. 57, No. 679 (1939), p. 38.

nolic derivatives are among the substances used for this purpose.

Many substances are used to make jute water-resistant. Flame proofing is accomplished by a treatment with an aqueous solution of mineral salts. Mercerization with caustic soda results in an extreme swelling together with shrinkage. Loose fibers treated with caustic soda assume a curly, woolen-like appearance which permits their being mixed with wool. Jute is often combined with wool in the production of rugs where the jute is used as the backing. Its most important use is in the production of burlap bags and cheap twine. Unless especially treated, jute cannot be dry cleaned or washed so its use is limited.

A synthetic fiber, Zelljute, is produced in Germany. The production of this fiber was expected to reach 12,000 tons in 1940. This was about 10 per cent of the demand for jute at that time.

Ramie. Ramie is a bast fiber-producing plant which has been grown in India, China, and Formosa for several thousand years. There are two distinct types, the white under-leaf type which was introduced into Europe one hundred years ago, and the green under-leaf less hardy type sometimes known as Rhea which is seldom grown outside of the Orient. The fiber taken from the Ramie plant is often known as China-grass, and the handwoven fabric made from this fiber is known as Chinese linen or grass cloth. Unlike most fiber-yielding plants, ramie is seldom propagated from seeds but by cuttings of the root-stalks. In moist soil and warm weather shoots will appear in ten to fifteen days. These plants are then transplanted. The first crop of stalks is cut the second summer and for a period of five to ten years two or three crops a year may be cut. In China, where most of the ramie is produced, much of the work is still done by hand.

The fiber is separated from the green stalk and cleaned. The bark and the fiber are stripped from the stalk either before or after it is cut. The thin outer bark is then scraped away, usually by drawing it between a bamboo or bone knife and a bamboo thimble worn by the operator. Most of the

green coloring matter and some of the gums are removed with the bark. The scraped, cleaned ribbons of fibers are hung on rods in a cellar where they are dried by a charcoal fire. The following day the fiber is dried in the sun. The omission of the charcoal drying results in an inferior fiber.

Modern methods of decortication providing for the removal of fiber from the green stalk have been applied in Europe and the United States to the processing of ramie. Harvesting machines are being used to cut the plants which are deleafed by machinery. The green stalks are decorticated immediately. The apparatus used for this includes circular saws which skin the bark from the plant and at the same time remove the woody portion. Thus the fibers are quickly and inexpensively prepared for degumming.

The ramie fiber must be degummed before spinning into yarn. This is carried out as a manufacturing process. In the United States the gum is removed by acid and alkaline solutions, followed by washing in water. It is difficult to remove the gums without injury to the fiber. In China the gum is removed by repeated washings, resulting in a stronger fiber.

The degumming of ramie reduces a large portion of the fibers to the individual cells. These cells are longer than the cells of any other fiber, but they are quite irregular in size. The length of the individual cells of ramie is from one-half to ten inches, in comparison with from one-half to two and one-half inches for the flax cells. The diameter of the flax fiber is from $\frac{6}{10,000}$ to $\frac{15}{10,000}$ of an inch, while that of the ramie fiber is from $\frac{20}{10,000}$ to $\frac{30}{10,000}$ of an inch. Ramie fibers require special machinery for spinning into yarn.

Ramie possesses properties which make it superior to other fibers in some respects. It is the strongest natural fiber; has longer average staple than wool, being from six to eight inches in length; has greater resistance to mildew than linen; absorbs liquids; and its luster is excelled only by silk. Ramie has the disadvantage of being low in elasticity and torsion, which results in fabrics that break readily under bending or strain. Spinning ramie on the conventional machinery used for cotton or woolen yarn is difficult. Much of its best qualities are

lost if it is cut to the length which would permit it to be handled on short-fiber machinery. It would require flax spinning machinery to handle ramie in its original length, and practically no flax spinning machinery exists in this country.

William B. Dall,¹ in his recent article summarizing available information on ramie, states that it is doubtful whether any other commodity or product has so high a ratio of failures among those who have sought to utilize it as ramie. In his opinion, of all the 65 enterprises from 1918 to 1945 in the United States of which he had record, only those of most recent origin are still in business. He quotes an authority as saying, "Unless some wholly new element enters into the picture, such as a definitely new process or a new use, the odds are decidedly against the success of any ramie project."

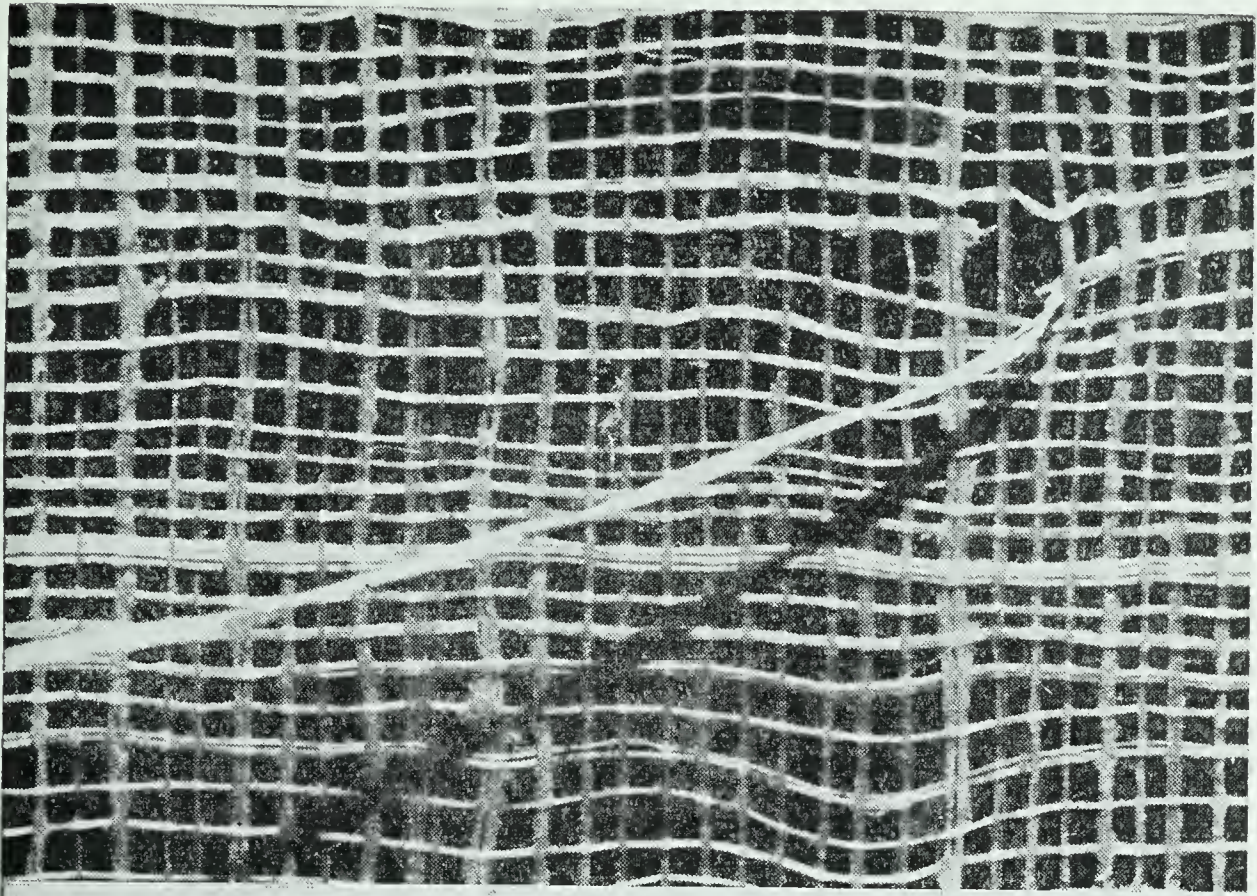
The production and processing of ramie are being studied widely at this time, and ramie fibers are being used alone and blended with other fibers in the production of various types of fabrics.

Hemp. Hemp, another fiber obtained from the stem of the plant, is grown to a limited extent in the United States. Hemp is also produced in Russia, Yugoslavia, Roumania, and Poland, but little fiber is imported from these countries. Some "water-retted" hemp is imported from Italy. In the United States the stalks are only partially retted and the fibers are then removed by machinery. Many states have successfully grown hemp for fiber production, but in 1945 it was grown commercially only in Kentucky and Wisconsin. (See page 337.) The production of hemp in the United States for 1945 was given as 6,762,000 pounds.² American hemp has been unable to withstand the competition of other fibers and has been replaced to a great extent by jute, which is much cheaper but less durable. Cotton has also replaced hemp to some extent.

In 1919 hemp fiber sold for 22 cents a pound, but in 1938 it brought only 11.5 cents a pound. The crop yields from 700 to 1,000 pounds of fibers per acre. Hemp is harvested by machinery designed for the purpose. It should be harvested

¹ William B. Dall, "Ramie," *Textile World*, Vol. 95, No. 12, 1945, p. 93.

² Crops and Markets, U. S. Dept. of Agr., Vol. 23, No. 1, 1946.



Courtesy Dole Hawaiian Pineapple Co.

Top, fabric woven with fine pina fibers. Note broken end and irregularity in the size of the fibers. Bottom, pineapple field on Oahu.

when in bloom, as this early harvesting provides the best time for retting. The green stalks are spread on the stubble and left until sufficient decomposition has taken place to permit the bark to be removed from the stem. Under favorable conditions retting may be complete within two or three weeks. In dry, cool weather retting may require many weeks. The retted straw is bound in bundles and placed in shocks to cure. When well cured, the straw is stacked either in the field or at the mill. Because hemp is unaffected by salt water, it is used mostly for cordage, fish lines, and sail cloth.

Pina cloth. Pina cloth is made only in the Philippines, where it is constructed from the unspun fibers taken from the leaves of the cultivated pineapple plant. The finer qualities are made only in small pieces, since single fibers are used. (See page 343.) The natural color of the fiber is almost white, with a slight yellow tinge, but all colors can be obtained. The lovely fine fabrics made into handkerchiefs and luncheon sets are exquisitely and often elaborately embroidered.

The native dress of the Filipinos includes a pina cloth shirt for the men and a pina cloth blouse for the women. The fabric is soft and delicate, yet with a natural crispness which gives to the native costume its peculiar beauty.

Palconia. Palconia is a fiber made from the bark of the redwood tree. The name is coined from the company which discovered this use for a waste product, The Pacific Lumber Company. The fibers lie between the inner and outer layers of bark and are only one-eighth to one-half inch long. Because these fibers are spiral in form they have been successfully blended with wool fibers of much longer staple and constructed into comparatively heavy cloth suitable for mackinaws and blankets. Felts of 50 per cent wool fibers and 50 per cent redwood fibers have been made for use in men's hats.

As Palconia is a vegetable fiber, it dyes the same as other cellulose material. Unlike other vegetable fibers, however, it fulls readily so that blending it with wool does not interfere with felting operations. In their present state of development Palconia fibers cannot be used alone in the construction of satisfactory fabrics.

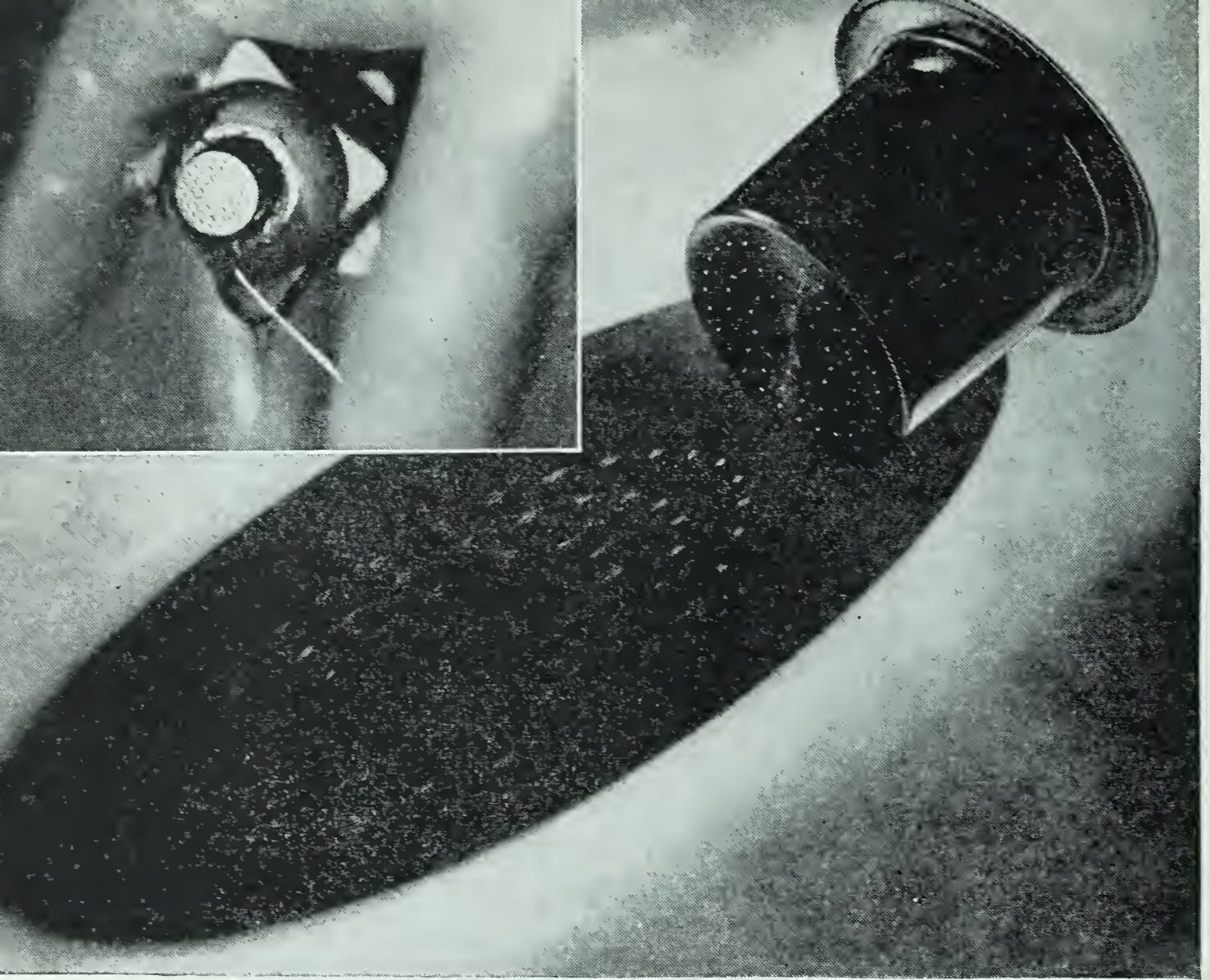
Unit Six

SYNTHETIC FIBERS: SCIENCE IN COMPETITION WITH NATURE

THE phenomenal development and improvement of man-made fibers is one of the scientific wonders of the age. The first successful attempts to synthesize fibers were made scarcely more than half a century ago in an effort to simulate the action and products of the silkworm. Mulberry leaves were chemically digested and the resultant solution was forced through fine orifices known as spinnerettes. This material had not been changed to protein but remained cellulose as before. "Artificial silk" had a high luster and resembled silk somewhat in appearance but lacked the elasticity, strength, and cohesion of natural silk. The poor quality of the materials first produced tended to cast anything bearing the name artificial silk into disregard and to create an antagonism in the mind of the purchaser. An effort was made to overcome the implication and assist the synthetic fiber in standing on its own merits by adopting the name "rayon." Today the tendency is for the manufacturers not only to designate their product as rayon, but also to add a trade name which represents the process of manufacture.

Within the past few years many modifications have been made of the early synthetic fibers, and new ones continue to appear on the market. As rayon is the name given to those synthetic fibers which are produced from a cellulose base, the new fibers using protein or synthetic resins for their raw material cannot be included in the classification of rayon.

Azlon is the generic term that has been accepted for fibers

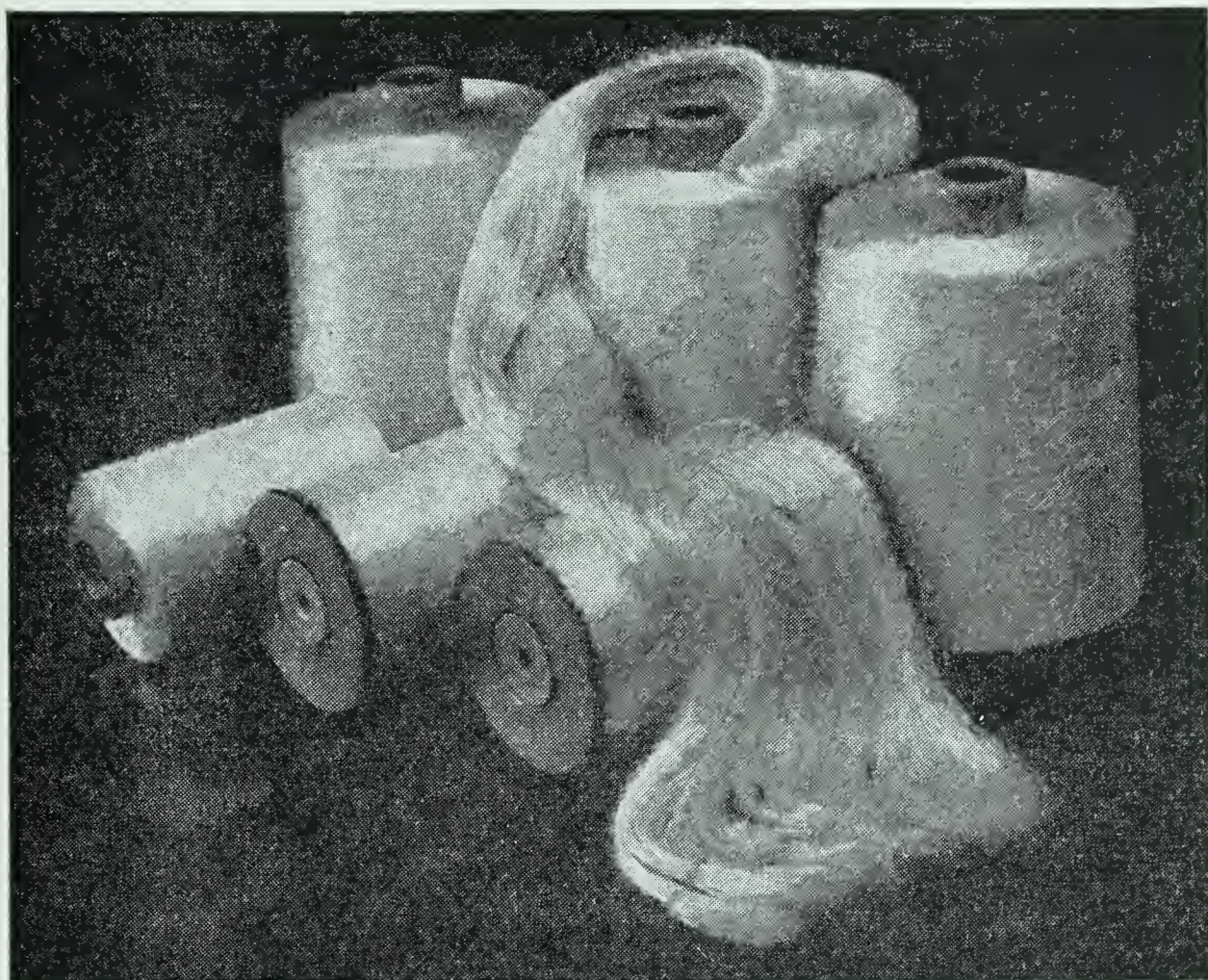


Courtesy American Viscose Corporation

Spinnerettes. The solidified rayon is forced through the small holes in the spinnerettes.

and filaments made by man from natural proteins or derivatives thereof, with or without lesser amounts of non-fiber-forming materials. This group includes fibers made from casein, soybeans, cornmeal, peanuts and other protein materials. No generic term has yet been accepted for those fibers produced from synthetic resins and related substances.

The basis of rayon is cellulose, usually in the form of cotton linters or wood pulp which is cleaned, chemically dissolved, purified, and bleached. The purified solution is forced, by mechanical means, through small orifices and solidified. (See page 346.) Thus fine filaments are formed which are later bleached and more or less twisted into yarn. These yarns are mechanically wound on reels in skein form or onto bobbins or cones, depending upon the use for which they are intended. The weaving mills handle skeins and some cones, and the knitting mills handle bobbins and some cones.



Courtesy American Viscose Corporation

Various forms in which synthetic fibers are marketed to the weaving and knitting mills.

Today, four methods are employed commercially for the production of rayon. The difference in the raw material, the chemical solvents used, and the variation in the methods of handling, result in the production of fibers differing in chemical composition and in chemical and physical properties. Various methods of construction and finish add to the differences found in the fabric for sale on the market.

PROBLEM 1. HOW IS RAYON PRODUCED?

The story of rayon from its beginning to the present time is the story of an idea that originated more than 200 years ago but was made a reality little more than fifty years ago. The term rayon is but 20 years old.

In 1665 Robert Hooke,¹ a former scientist, wrote:

I have often thought that probably there might be a way found out, to make an artificial glutinous composition, much resembling, if not fully as good, nay better, than that Excrement, or whatever other substance it be out of which, the Silk-worm wire-draws his clew. If such a composition were found, it were certainly an easie matter to find very quick ways of drawing it out into small wires for use.

Little advance toward the discovery of such a process was noted until the report of the French physicist and naturalist, René A. de Réaumur, in 1754. He said briefly that it was possible to make varnishes unaffected by solvents, water, and the heat to which clothing is subjected, and which possess the essential qualities of silk. As varnishes properly dried have no odor, why not make varnishes into threads to imitate those of silk?

Early experiments. In 1840 F. G. Keller, the Saxon weaver, invented a chemical process of dissolving wood pulp, the importance of which was recognized by those who followed him. Contemporary with Keller, Louis Schwab, of Manchester, England, experimented with substances that could be drawn through fine holes into filaments or threads. His work resulted in the invention of a machine for producing synthetic fibers, which was the forerunner of the synthetic fiber spinning machines of today.

None of the substances used at that time yielded satisfactory fiber production. The search became intense and finally resulted in the discovery of nitrocellulose by Schoenbein in 1845. Its properties were studied, especially with regard to those necessary for the preparation of yarn. Audemars, of Lausanne, experimented with the material and in 1855 obtained a patent for transforming the dissolved nitrocellulose into fine threads which he called artificial silk.

Count Hilaire de Chardonnet, a French scientist, produced the first synthetic fiber having commercial value as a textile. In 1884 he produced his first fiber, using pulp obtained from

¹ Chas. E. Mullin, *Acetate Silk and Its Dyes*, p. 17. D. Van Nostrand Co., New York, 1927.

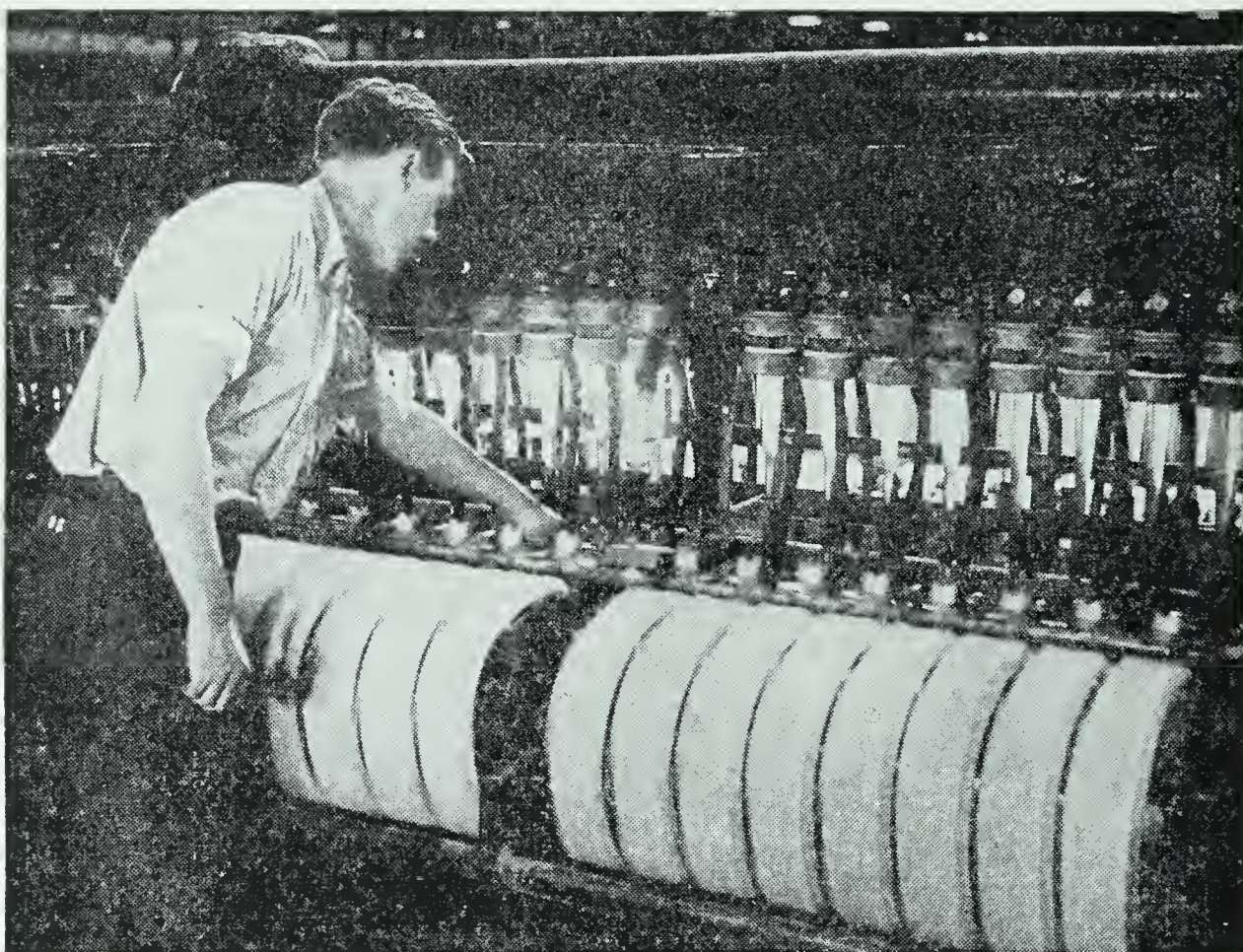
the mulberry tree as his chief raw material. In 1889 capitalists provided him with funds, and the construction of the first synthetic fiber factory was started. Within two years profits were being realized. Thus was the synthetic-fiber industry born. The method was called the nitrocellulose process and has been developed and modified since that time. Although his first work was done with the cellulose of mulberry leaves, Chardonnet found that wood pulp and cotton cellulose were admirably adapted to this purpose.

Four processes. The *Chardonnet*, *nitrocellulose*, or *collodion process* consists in dissolving nitrocellulose in a solution of alcohol and ether, and forcing this solution through small orifices, thus forming fine filaments which are hardened, denitrated, bleached, and washed. This process, the first method used, has been largely replaced by other types. Hungary and Brazil are two countries still using this process.

At the same time that the commercial production of nitrocellulose was being carried on, other chemists were experimenting with solutions of cellulose in an ammoniacal solution of copper salts in an effort to produce fine filaments. Their efforts resulted in the development of a second method for producing synthetic textile fibers which is known as the *cuprammonium process*. In this process cellulose digested in copper sulfate is spun into fine filaments and hardened in an acid bath.

In 1892 two English scientists, Cross and Bevan, discovered that certain cellulose compounds could be produced that were soluble in water. By treating cellulose with sodium hydroxide and then treating the alkali-cellulose with carbon disulfide, a soluble cellulose xanthate, a brown viscous solution, was produced. Great difficulty was experienced in handling the resultant filaments while wet. The invention of the centrifugal method of spinning overcame this difficulty and made possible the manufacture of rayon by the *viscose process*. This method, because it was less expensive than previous processes, developed rapidly.

The fourth method of dissolving cellulose and forming it into fine filaments was worked out about this same time.



Courtesy American Bemberg Corporation

Spinning and making skeins of Bemberg (cuprammonium) rayon yarns by the unique stretch-spinning process.

These filaments were not regenerated cellulose as were the fibers produced by the other three processes but were formed from a cellulose derivative, cellulose acetate. In this method *cellulose acetate* is dissolved in acetone and solidified in water or warm air. Textile fibers were not developed to any great extent by this method until about 1918. Many difficulties that were encountered when attempts were made to spin fibers of this type prevented its earlier development. During the war a large and expensive plant was equipped for the production of airplane wing "dope" made from cellulose acetate. At the close of the war the problem arose of converting this plant into a peacetime factory. After many difficulties the manufacture from cellulose acetate of a fiber known as "Celanese" was developed there on a practical basis.

Fabrics on the market today constructed either wholly or in part from synthetic fibers are made possible by the applica-

tion of one or more of these methods. The characteristics of the fibers depend to a great extent upon the method used.

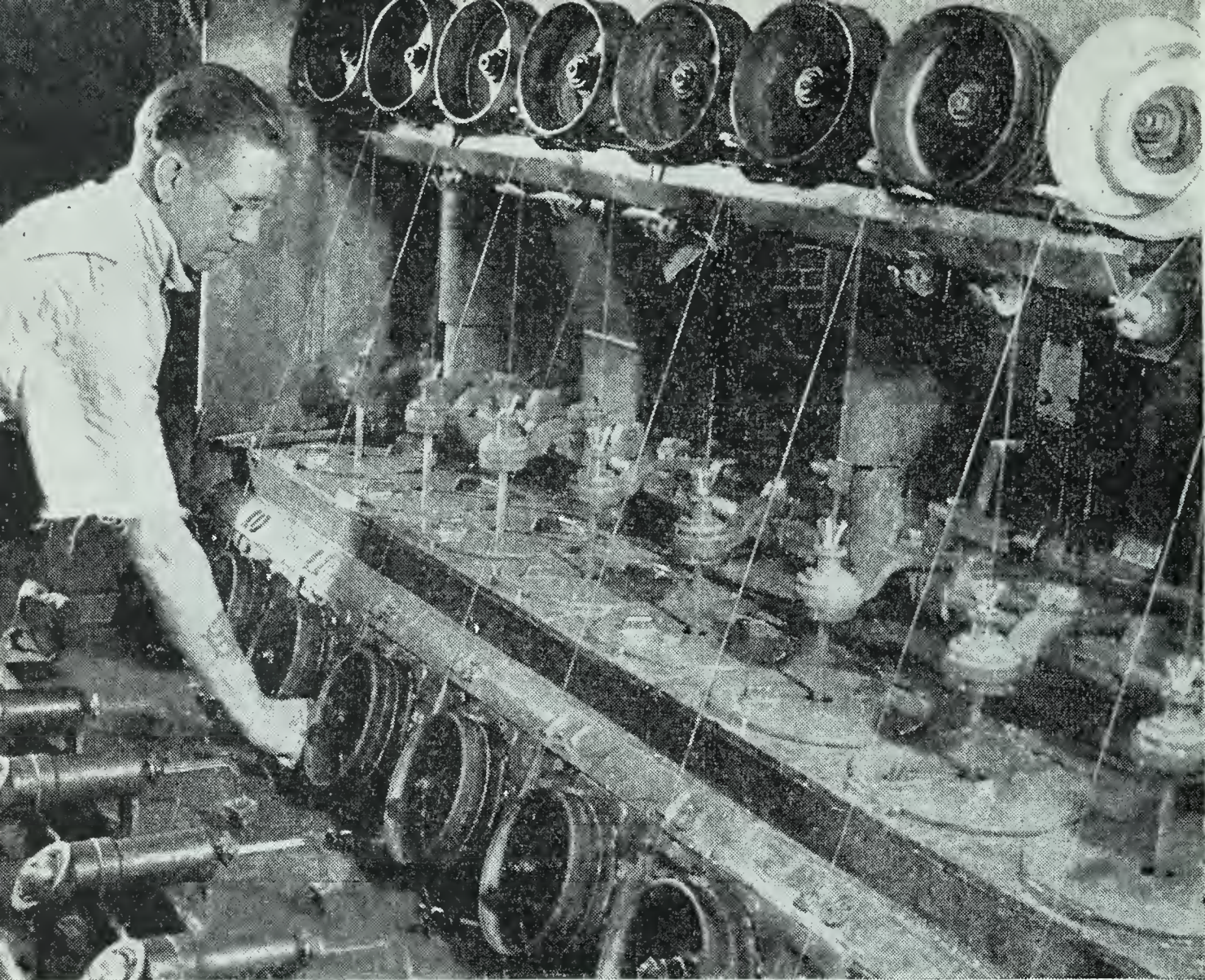
PROBLEM 2. HOW DOES THE PROCESS USED INFLUENCE THE PRODUCT?

Cellulose for the production of rayon is obtained principally from cotton and wood pulp but may be secured from straw. Straws of different kinds contain about 35 per cent of cellulose, wood pulp contains 60 per cent of cellulose, and cotton has as high as 90 per cent. Wood pulp usually costs less than half as much a pound as cotton linters, making fibers derived from wood pulp of lower cost. The price is much more constant also.

Chemical and physical properties. From whatever source cellulose is obtained, it is built up of glucose units and is fibrous in nature. However, some variations are believed to exist in the chemical structure and purity of cellulose from different sources that may affect its reactivity to chemical and mechanical treatment. One might expect the three types of rayon that are regenerated cellulose to possess certain properties in common. This may be more or less true of their chemical properties, but their individual physical structure causes them to have different physical properties.

It is quite evident that a cellulose derivative such as cellulose acetate would differ both chemically and physically from a regenerated cellulose. Therefore we would expect the cellulose acetate process yarns to be unlike those produced by the other processes, as indeed they are.

Perhaps dyeing is the process in which difference in the chemical reactivity of the various rayon fibers is most evident. In the early days of the rayon industry it was customary to say, "Rayon dyes the same as cotton"; now such a generality is shunned. The individual reactivity of the rayons is due largely to the process of manufacture. It has been found that cuprammonium and viscose fibers manifest about the same affinity for direct cotton dyes, though the cuprammonium tends to give a somewhat deeper shade.

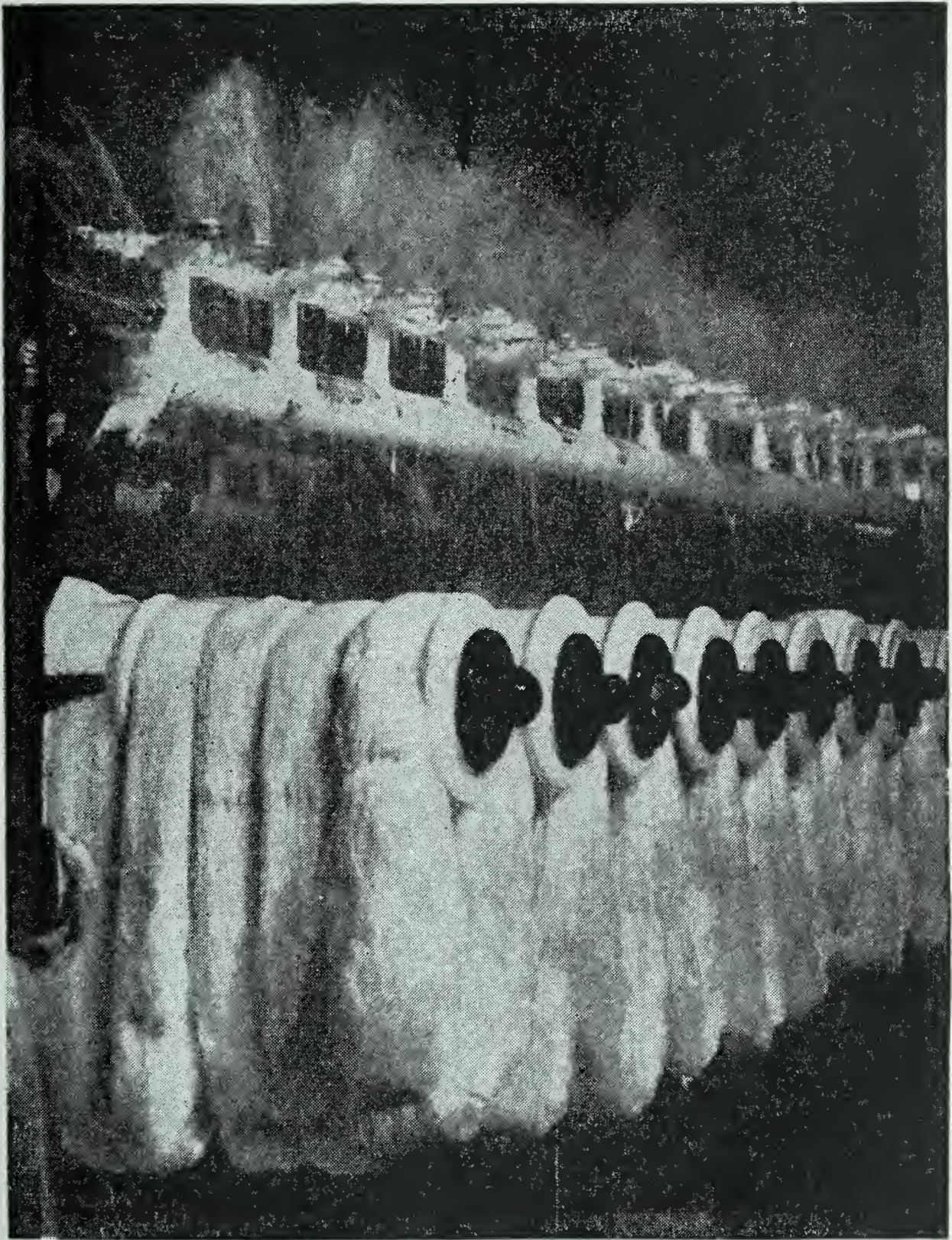


Courtesy American Viscose Corporation, photo by Roy Pinney

Viscose rayon yarn spinning machine. The white lines up the face of the machine are the rayon threads as they leave the chemical bath.

Acid dyes have been shown to have small affinity for any of these fibers. With basic dyestuffs nitrocellulose shows the greatest affinity and viscose fiber shows the second greatest affinity. Both nitrocellulose and viscose fiber rank above the cuprammonium in reactivity.

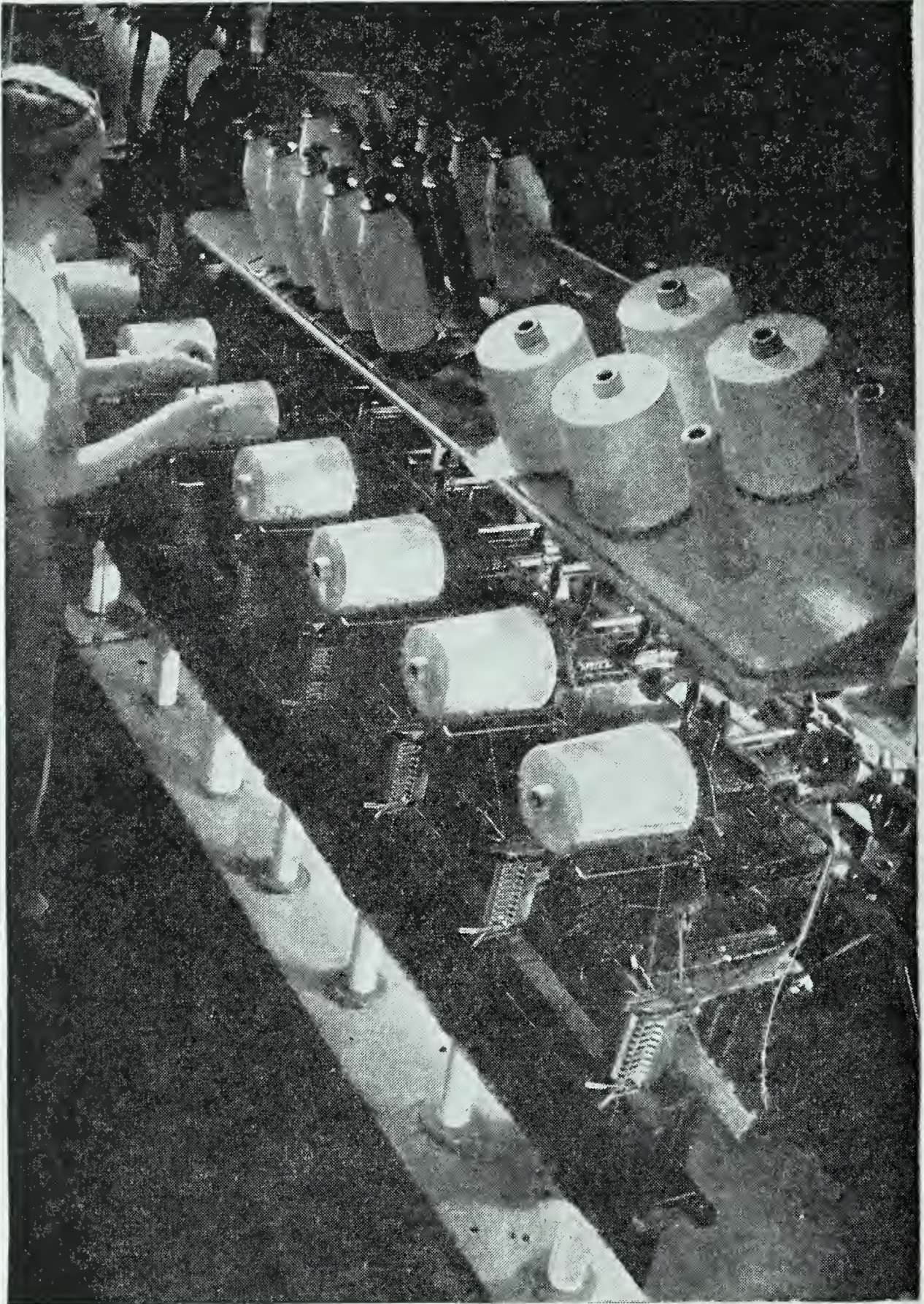
The dyeing of cellulose acetate fibers constitutes a unique problem, as would be indicated by its composition. It was impossible to dye these fibers with direct cotton dyestuffs, a fact which doubtless delayed the wide acceptance of this fiber in industry. Some types of dyes which were tried proved to be injurious to the fiber. The discovery that certain insoluble dyestuffs could be made soluble by treatment with Turkey-red oil made effective dyestuffs available for the cellulose acetate fibers. Because of the characteristic dyeing properties of this fiber it is widely used in obtaining color contrast effects both with other rayons and with the natural fibers.



Courtesy American Bemberg Corporation

Washing skeins of cuprammonium rayon yarn to remove traces of copper.

Identifying the synthetic fibers. Each type of rayon has certain chemical properties which may serve as a means of identification. Because of a few impurities left in the yarn—such



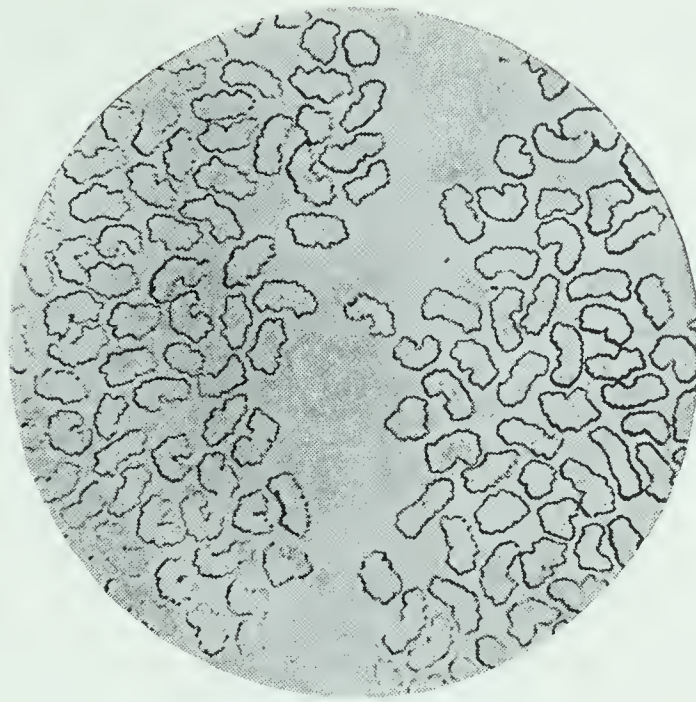
Courtesy E. I. DuPont de Nemours and Co.

"Acele" acetate rayon being wound on cones from the "pirns."

as the copper from the cuprammonium process, the nitrogen compounds from the nitrocellulose process, and the sulfur compounds from the viscose process—the fibers give characteristic reactions with certain chemicals.

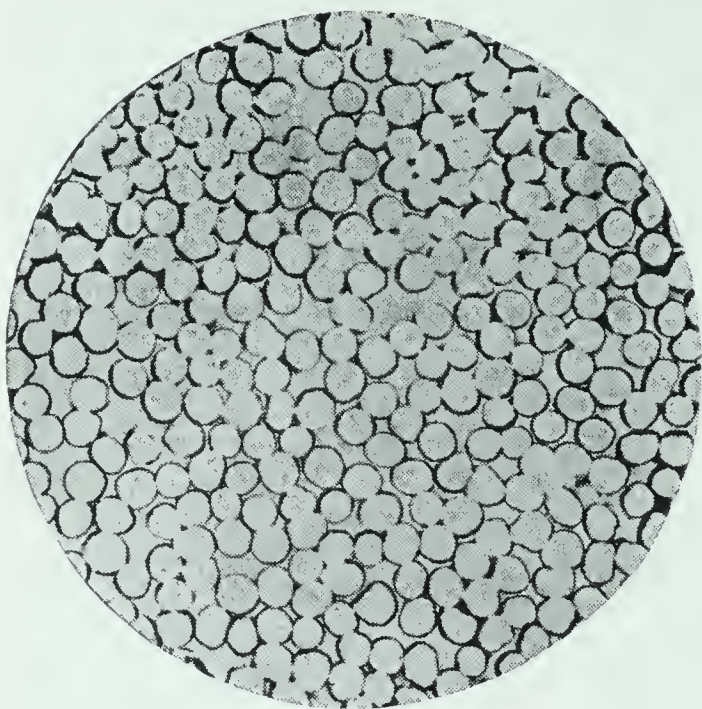
Probably the most noticeable characteristic of the first rayons was their natural high luster. This luster was first considered very attractive, but it later proved to be a liability rather than an asset. The early rayons did not possess the soft, rich luster of silk but more of a metallic sheen which was thought to denote artificiality and cheapness. By variation in treatment this unsatisfactory luster has been modified. This was first accomplished by delustering yarns already manufactured, but the dull finish obtained by this method was often not permanent. Later a variation in the manufacturing process permitted the production of lusterless yarns with a soft finish. This is frequently accomplished by adding finely divided pigment to the spinning solution. Combinations of lustrous and nonlustrous yarns offer great opportunity for design. Reduction in the size of the rayon filament so that many filaments instead of a few constitute a standard yarn has decreased the lustrous effect of rayon.

The shape of the various kinds of rayon fibers as shown by their cross section is more or less characteristic of the type and may be used as an aid in identifying them. However, this cannot be taken as positive proof of the type, as it can be and is varied. A corrugated and flattened form is typical of most viscose fibers. The dull fibers are identified by the presence of the specks of pigment. These are easily seen under the micro-



Courtesy American Bemberg Corporation

Cross section of viscose fibers.



Courtesy American Bemberg Corporation

Cross sections of cuprammonium fibers.

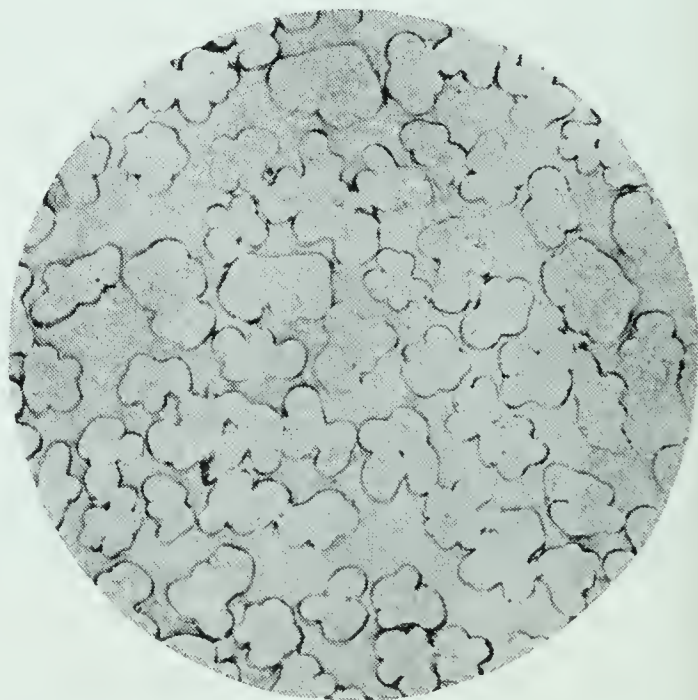
whereas an irregular, flattened fiber will remain flat as pressed. This is counteracted in yarns containing many fine filaments.

Alkaline solutions have a tendering effect on most rayon fibers. The effect of alkaline solutions on cellulose acetate is so great as to require the presence of certain protective agencies during processing. However, under the controlled conditions necessary for mercerizing, strong solutions of caustic alkali may be used on rayon without injury. This permits the mercerization of the cotton in cotton and rayon mixtures.

Though, in general, acids weaken rayons, some acids used in certain processes under carefully controlled con-

scope. The round small filaments are typical of cuprammonium rayon. (See picture at left.)

Nitrocellulose and cellulose acetate rayons may resemble each other so much as to render distinction difficult. (See below.) The shape of the cross section of the fiber has a definite effect upon the covering power. A round, smooth filament will tend to pack and form a round yarn,



Courtesy American Bemberg Corporation

Cross sections of nitrocellulose fibers.

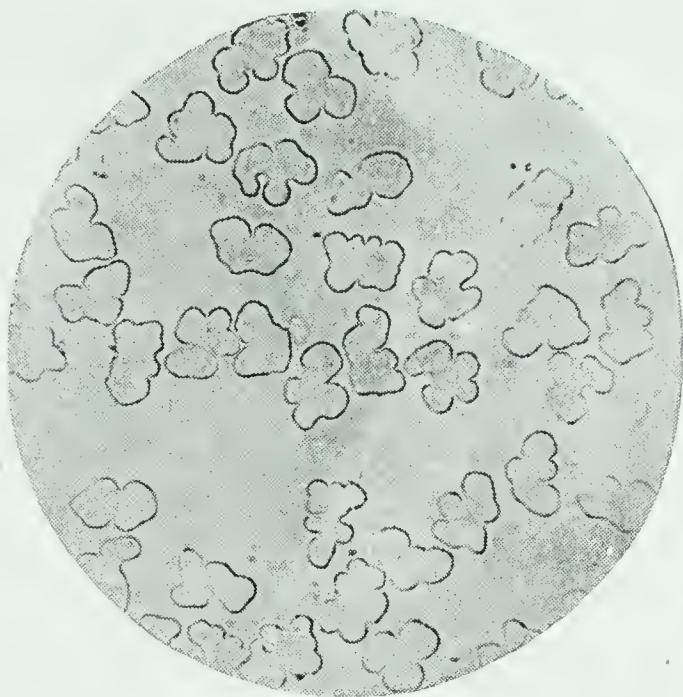
ditions show no apparent injurious effect. As with the other fibers, the organic acids have a less harmful effect than do the inorganic acids. The scrooping of certain rayons may be produced by the action of a weak acid which is allowed to remain in the fiber or fabric.

There is a great difference in the moisture content of these fibers.

It is stated that at standard conditions of relative humidity and temperature, viscose, nitrocellulose, and cuprammonium hold eleven per cent moisture; that held by cellulose acetate is 6.5 per cent or less. Water causes the fibers to swell and lose strength. When dry the fibers regain their original strength. The production of fine filaments with many fibers combined in the yarn has been one method of increasing the strength.

When first produced, the wet strength of the rayons was very low but careful research has increased the wet strength 300 per cent and the dry strength somewhat. Scientific control of the chemical and physical aspect of manufacture by well-trained personnel has helped to improve the properties of rayon. For example, the application of stretch spinning to the processing of rayon, in the production of high-tenacity tire cord, resulted in a great gain in the strength of rayon fibers. This process causes a rearrangement of the molecules in the fiber, placing them parallel, thus bringing powerful intermolecular forces into play.

A twisted yarn tends to retain its strength when wet and also to have a reduced luster. This type of yarn does not pull out or become frayed so quickly as an untwisted yarn. Yarns of any type of rayon may be manufactured with a twist, al-



Courtesy American Bemberg Corporation

Cross sections of cellulose acetate fibers.

though some kinds of rayon yarns lend themselves more readily than others to crepe effects.

Effect of heat. The regenerated rayons, those produced by the viscose, nitrocellulose, and cuprammonium processes, are no more sensitive to heat than are silks. The luster of cellulose acetate rayon may be destroyed by boiling water, and a too high temperature in ironing melts this fiber. No type of white rayon will yellow because of heat applied in ironing.

Acetate and cuprammonium yarns. The producers of acetate yarn claim that it possesses an evenness of surface and an evenness of dyeing that make it especially valuable for the production of quality fabrics such as twills, moirés, satins, voiles, and taffetas. Some of these fabrics are made of acetate yarn alone, others of a combination of this yarn with other rayon, wool, or cotton.

According to the fourteenth edition of the *Encyclopaedia Britannica*, the cuprammonium process gives a product which approaches real silk in fineness and other properties.

The *size* of rayon yarns is determined in deniers on the same basis as that used for raw silk.

A comparison of the density of the fibers shows acetate rayon to be the lightest of the cellulose fibers, with the other rayons heavier than the natural vegetable fibers.

DENSITIES OF TEXTILE FIBERS ¹

Rabbit hair	1.12
Silk (boiled off)	1.25
Tussah silk	1.27
Wool (also mohair, camel, etc.)	1.32
Acetate rayon	1.33
Cotton	1.48
Linen	1.50
Ramie	1.51
Viscose rayon	1.52
Cuprammonium rayon	1.52
Nitrocellulose rayon	1.54

¹ Frederick A. Mannerich, "Microscopical Analysis of Mixed Textile Fibers," *Rayon Textile Monthly*, Vol. 20, No. 3 (1939), p. 142.

PROBLEM 3. HOW HAS THE RAYON
INDUSTRY DEVELOPED?

When rayon was first put on the market, textile manufacturers were slow to accept it. They were skeptical as to the possibility of using this fiber even in combination with other textiles. At first difficulty was experienced in the handling of these fibers and the results were not altogether satisfactory. The consumer, too, was doubtful of its value and did not readily accept fabrics constructed from it. To avoid this hos-

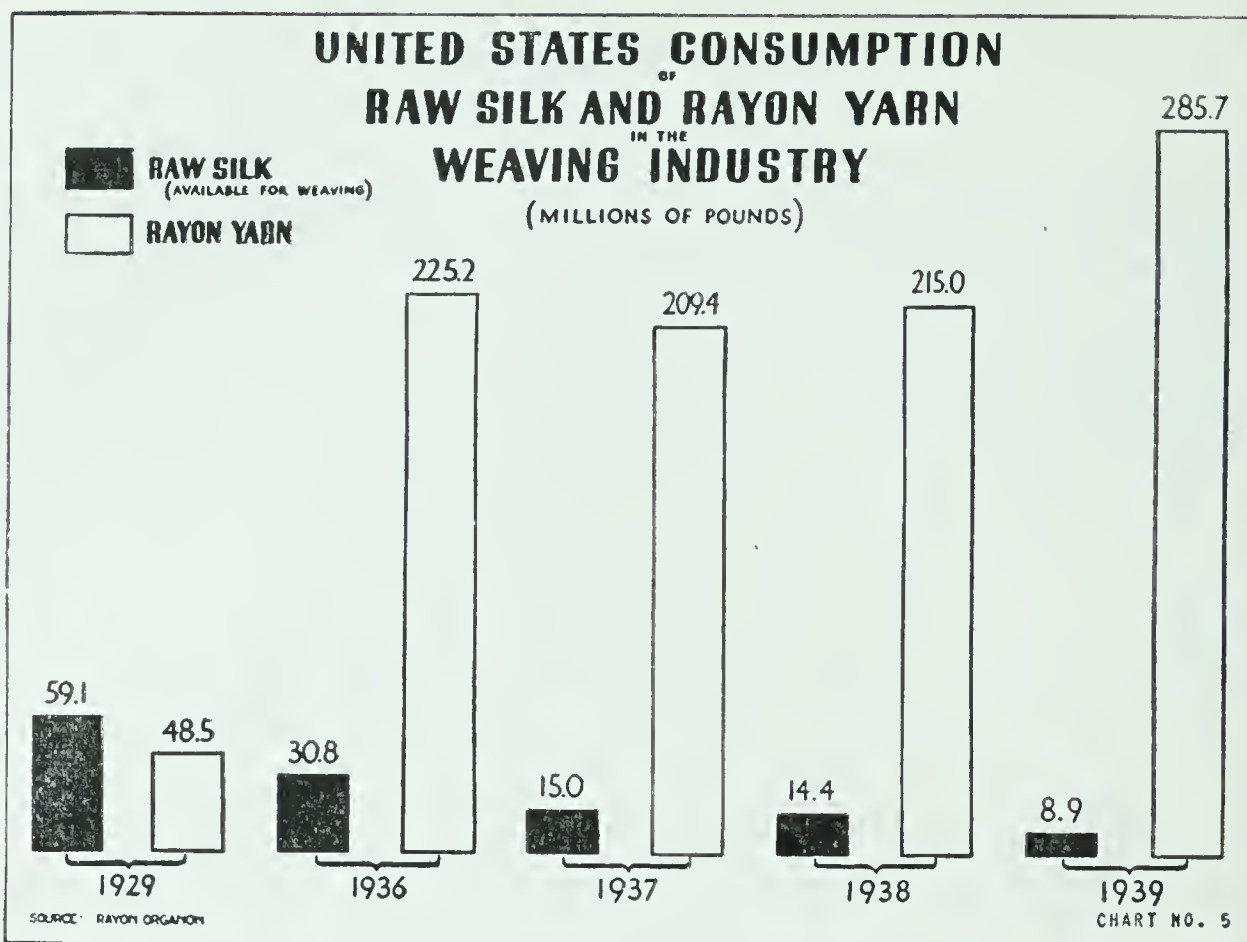
WORLD RAYON PRODUCTION ¹

MILLIONS OF POUNDS

	FILAMENT YARN	STAPLE	TOTAL RAYON
1940.....	1,182	1,293	2,475
1941.....	1,272	1,563	2,835
1942.....	1,200	1,480	2,680
1943.....	1,163	1,410	2,573
1944.....	1,033	1,049	2,082
1945.....	934	596	1,530
1946.....	1,100	700	1,800

¹ *Rayon Organon*, Feb. 1947, p. 19.

tile reaction some manufacturers made the mistake of selling rayon as silk. Deception is rarely a sound basis for the development of any new project. Further, rayon required special care and could not be satisfactorily handled by methods approved for silk. At first the market developed slowly, but the improvements in the fibers, especially the reduction of the size and luster, and of the cost, have done much to increase its consumption. The production of better fibers together with improved and adjusted machinery for handling them resulted in satisfactory fabrics at lower cost. The selling of rayon on its own merits with correct instructions as to its care has increased the demand for this fiber and has overcome to a great extent the prejudice that existed against it. The utilization of rayon in combination with other fibers to obtain variety and



Courtesy *Rayon Textile Monthly*

Graphic picture of the replacement of silk by rayon in the weaving industry.

decoration has opened up many new channels for these fibers.

Increased production. The increase in the production of rayon was gradual for the first period of its development, but has been phenomenal since 1920.

In the first year of rayon manufacture there were only four countries producing this fiber, but in 1938, twenty-two countries were producing rayon filament yarn. The United States began the production of rayon in 1911. By 1946 the production of 677,000,000 pounds of filament yarn represented slightly more than half of the world's output.

The extent to which rayon replaced silk in the weaving industry is shown by the graph above.

Processes most used. Of the twenty-two countries producing rayon, only one country, Hungary, does not use the viscose method. The filament rayon produced by the viscose method in 1946 constituted 75 per cent of total production.

The great production of rayon by the viscose method is due largely to the cheapness of the chemicals used (caustic soda and carbon bisulfide). The greatest single development in viscose rayon in recent years has been the increased production of strong tough yarns. During the war these had wide military use, a great amount going into tire cord. Peacetime use of these high-strength yarns will be in women's hosiery, upholstery, luggage, carpet backing, and many industrial fabrics. These high-strength filaments are of large denier. In contrast, viscose rayon semi-strong yarns of one-denier filaments have been developed. These fine filament yarns have permitted the production of attractive fabrics not possible previously.

The cellulose acetate rayon process is now the most expensive one. The yarn is different from other types and is considered to be superior in certain ways. Production by this method has made rapid gains, especially in the United States. An English firm was the first to produce a textile fiber of this type. The American Celanese Corporation, a branch of the English concern, was established in 1925. The output of Celanese by this company the first year was 1,500,000 pounds. The world production of filament rayon by the acetate process constituted 23 per cent of the total rayon production in 1946. The United States produced 74 per cent of the world's output of acetate filament rayon yarn in 1946.

Acetate rayon is available today in many forms, each of which has been developed to meet specific needs. It varies in luster from matt to very bright and is as small as one denier. Some types are equal to or stronger than silk. When it was recognized that acetate rayon was a unique fiber with qualities different from all other fibers, its success was assured. The special dyes developed to dye cellulose-acetate rayon have been found to be also exceptionally successful in the dyeing of nylon and vinyon.

Only two per cent of rayon filament yarn is produced by the cuprammonium process and less than one per cent by the nitrocellulose process.

Rayon is often sold by a trade name which may not indicate

the process of manufacture. In so far as viscose is concerned, there is seldom a label designating the type of manufacturing process used. However, cellulose-acetate and cuprammonium usually carry this information with their trade mark. All- rayon and high percentage rayon fabrics make up approximately 95 per cent of synthetic fiber fabrics.

Slit-cellulose film yarn is another form of rayon. Transparent cellulose film sheets have been produced for several years. However, not until recently have the cellulose film sheets been slit into narrow enough strips to be used as yarns either alone or in combinations with other yarns for the production of woven and knitted fabrics.

The cellulose film sheets are produced the same as for rayon fibers, except that instead of being forced through fine spinnerettes the liquid is formed into sheets. As soon as these sheets could be slit to $\frac{1}{64}$ inch or $\frac{1}{100}$ inch they became important as a decorative yarn.

Slit-cellulose yarns do not tarnish as metallic yarns do, yet they are brilliant and glittering. These yarns are strong, light in weight, and inflammable.

Slit-cellulose film yarns have been produced in staple lengths of from one to six inches. These staple fibers are being mixed with several kinds of fibers in the production of yarns to be used in practically all types of fabric. A variation of rayon filament yarn is known as abraded rayon. This yarn is produced by running a filament rayon yarn over a rough surface which snags and breaks some of the filaments. Both viscose and acetate yarns are being made as abraded rayon yarns.

PROBLEM 4. HOW HAS THE RAYON STAPLE FIBER BEEN DEVELOPED?

The production of staple fiber is the most outstanding development in the rayon industry. This fiber is made usually from rayon filament fibers by cutting them into the desired lengths. Rayon filament yarn is the type which was produced from the beginning of the rayon industry; but rayon staple fiber yarn was first developed by Germany during the World

War of 1914 to 1918. The development and manufacture of filament yarn has been in competition with the production of the natural fibers. The production and utilization of spun staple fiber yarn has been under the protection and guidance of the government in many countries. However, this is not true in the United States.

Rayon staple fiber is really a new fiber. It is defined as "rayon fibers of spinnable length, manufactured directly or by cutting continuous filaments." Rayon staple fiber is the raw material for the production of spun rayon yarns. According to the American Society for Testing Materials—Designation D258-37T,

[Spun rayon is] a yarn made from cut rayon filaments, the cut filaments being drawn out and twisted into a yarn by the usual spinning processes:

1. Cotton system of spinning (ring and mule)
2. Worsted system of spinning (modified Bradford, Cap or Ring)
3. Spun silk method of spinning (ring or mule)

The world production of rayon staple fiber reached its peak in 1942 with the production of 1,536,985,000 pounds. The output of rayon staple fiber increased more than 200 times in fourteen years. In 1946 the United States was the largest staple fiber producer with an output of 176,390,000 pounds. This was 31 per cent of the world total of 569,000,000 pounds.

Several methods have been successfully used in producing spun rayon yarns without having to card and comb the fibers. The tow-to-top process starts with rayon tow which is an untwisted rope made of several thousand continuous filaments of rayon. By one method the tow is broken between sets of rollers traveling at different speeds. This is known as the "Perlock Process." In other methods the tow is cut and then handled in such a manner that the cut fiber slivers are fed at a uniform speed and at the same time false twist is added by revolving the slivers in opposite directions. These methods of producing tops do not subject the fibers to the wear and tear of the carding and combing processes. The yarns are numbered ac-

according to the system by which they are spun as cotton counts, worsted or woolen counts, or as spun silk.

Studies of the structure and properties of the natural fibers have furnished much valuable information not only for a better utilization of the natural fibers, but also for the production of more satisfactory synthetic fibers. It has been shown that the minimum spinnable length of any fiber is one-half inch, and in order to make a satisfactory yarn, fibers must be no larger than $\frac{1}{700}$ of their length. Sea Island cotton which can be spun into fine counts has a diameter of $\frac{1}{5000}$ of the length, and the finest wools show this same proportion. The limit of fineness ratio is $\frac{1}{1000}$ and such fibers can be spun into only coarse yarns. For a fine yarn the minimum fineness ratio must be at least $\frac{1}{2000}$. This information is used by the producers of staple fibers in determining the fineness and length of fibers for specific uses. Fiber-cutting machinery has been developed by which rayon filaments may be cut to the desired lengths for the production of staple rayon fibers. The machinery so developed is now being used to cut the natural fibers either to secure fancy effects; to imitate other fibers; to spin the yarn on another type of machinery; or in an effort to produce yarns for a special purpose. Fibers that vary greatly in length are cut to lengths that will permit them to be blended; thus, the long linen fibers may be cut and blended with wool or cut to blend with staple rayon. Wool fibers too long to be spun on cotton machinery may be cut to the necessary size for this purpose.

Rayon staple fibers, unless especially treated, are straight and smooth; hence, they lack the cohesive characteristics of wool and cotton. When twisted into a spun yarn the ends of the fibers tend to protrude and give the yarn and fabric a hairy appearance. Many attempts have been made to overcome this difficulty by giving the fibers a rough surface and a twist or crimp that will be permanent to further processing.

Modified staple fiber. The practice of blending staple fiber with wool has made it desirable that rayon so used shall have not only the physical properties of wool but that these fibers possess the dyeing properties of the wool. This requirement

has resulted in efforts in spun rayon manufacture to produce a yarn with wool characteristics. Among the synthetic staple fibers which have been produced to blend with or take the place of wool are the modified rayon fibers which have been given a rough surface or a permanent crimp by some specific method, and the so-called animalized cellulose fibers, which are some type of rayon, usually viscose, to which a protein has been added before spinning.

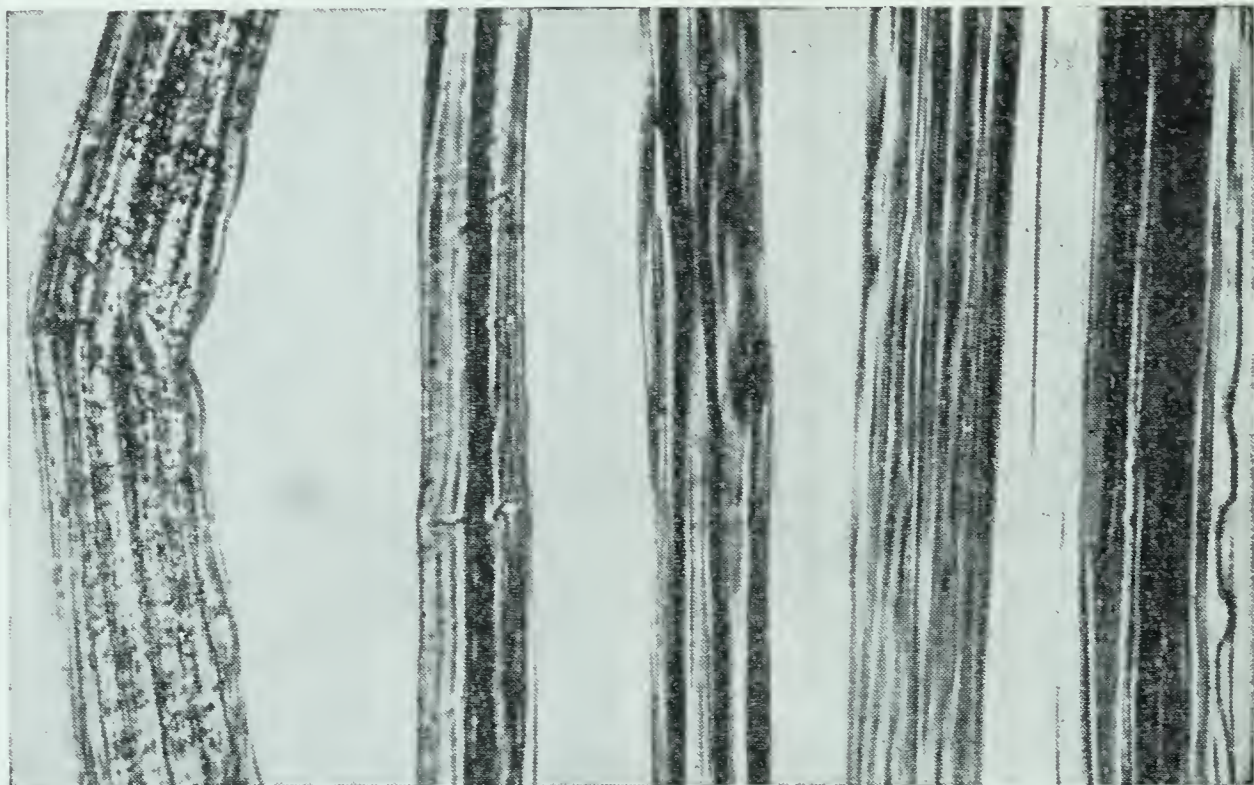


Courtesy American Viscose Corporation

Viscose rayon staple fiber.

Rayon staple fibers with a rough surface may be produced from viscose by regulating the ripening of the solution and the acidity of the coagulating bath. Another method is to coagulate and spin the xanthate solution and later regenerate the cellulose. Thus, what is normally accomplished in one process is done in two. By this method the spun xanthate yarns can be twisted or given a rough surface during the second process.

As early as 1930 investigation of the properties of various staple fibers was started by a carpet mill in an effort to find a synthetic fiber satisfactory for carpets. American and foreign staple fibers of several types were studied. By 1942 some 2,000,000 pounds of a special carpet type of rayon staple were being used. The first fibers that were tried were too soft and soiled readily. As other carpet mills joined in the research it was agreed that a semi-dull fiber of from three and one-half to four inches in length was the most satisfactory. Fibers in sizes of from five and one-half to 25 deniers and either crimped or more straight are available. Experimental tests have resulted in a fiber that furnishes satisfactory handle and appearance



Courtesy Werner von Bergen, Walter Krauss, and *Rayon Textile Monthly*

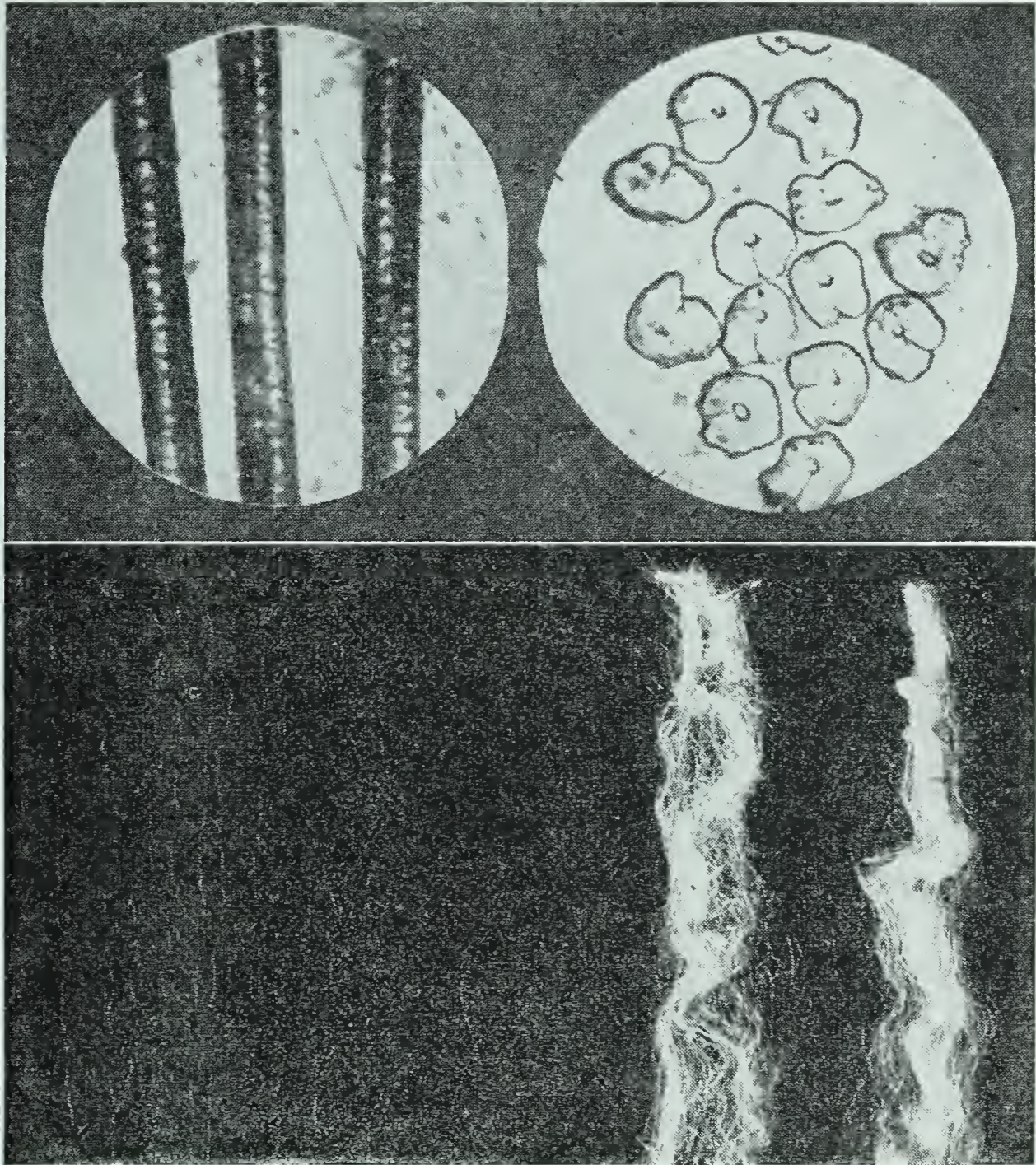
Differences in staple rayon fibers as shown by photomicrographs ($500\times$). Left, viscose dull, 3 denier; center, viscose Sylph bright, 4.5 denier; right, Celanese acetate, 5 denier.

and exceeds the abrasion resistance of similar carpet wools. A change in spinning conditions that resulted in a smoother fiber surface has increased the fiber's resistance to soiling.

Trifton, an American Viscose product, and Fiber D produced by Du Pont are two well-known viscose staple fibers now in use in the manufacture of carpets.

Teca is cellulose acetate staple fiber with a permanent crimp. This fiber imparts a wool-like character and a crush-resistant quality to the fabric in which it is used either alone or in combination with other fibers. Teca is produced in a variety of sizes with an average of eight to twelve crimps per inch, in bright or dull luster, and in many colors. Any desired length up to seven inches may be obtained in special finishes suitable for cotton, worsteds, or woolen processes.

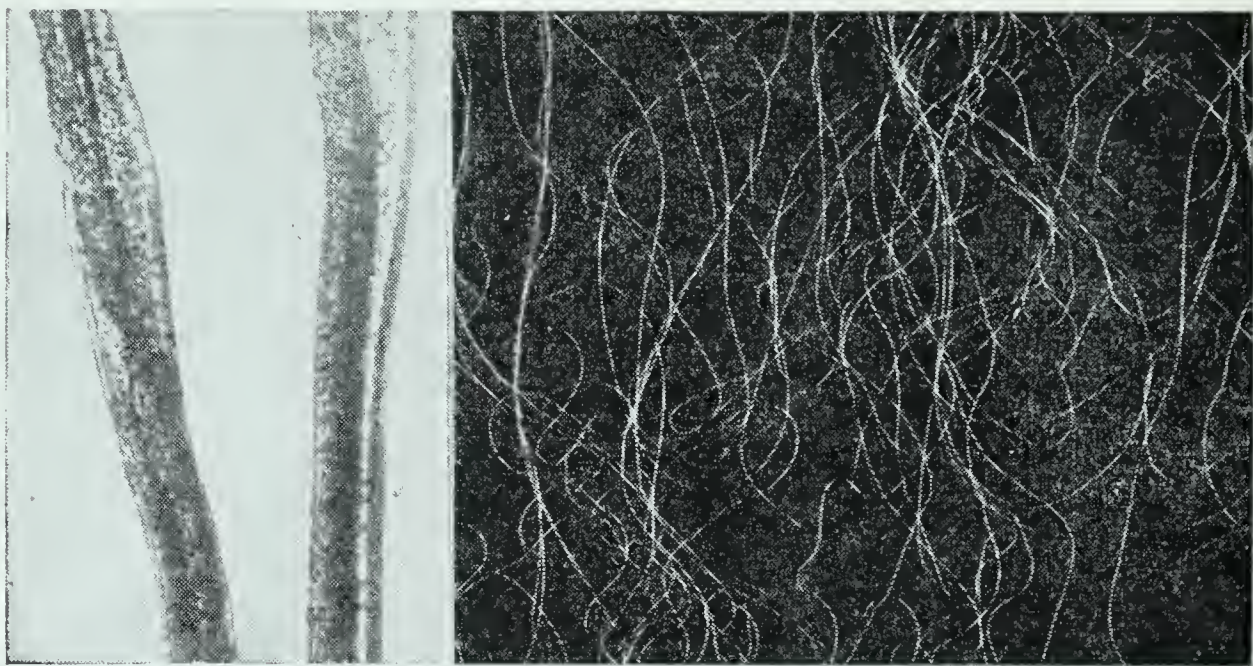
Animalized fibers are modified viscose fibers in which wool-dyeing properties are obtained by adding from 3 to 5 per cent of casein to the spinning solution. Cisalpa, produced in Italy, and Fibramine, produced in Belgium are animalized fibers.



Courtesy Rayon Textile Monthly

Photomicrographs of modified viscose produced by Kohorn process. The scaly surface and air-enclosed space closely resemble wool. The permanent waterproof crimp is also shown.

Basified viscose is another type of modified fiber possessing properties somewhat similar to that of the animalized fibers. This group has been chemically modified by the addition of synthetic resins so that they possess wool-dyeing properties. Among the fibers in this group are Courtauld's Rayolanda W. D. and Rayolanda X, and the German fibers Vistralon, Cupra-



Courtesy Werner von Bergen and Walter Krauss

Teca fiber under high and low power magnification.

lan, and Artiland. The Rayolanda fibers have been produced not as substitutes for wool but as a means of obtaining novelty effects by mixing them with wool. The German fibers are used as a substitute for wool. The wool-dyeing properties of the two Rayolanda yarns differ; thus, a combination of them

CHARACTERISTICS OF VISCOSE RAYON FIBERS

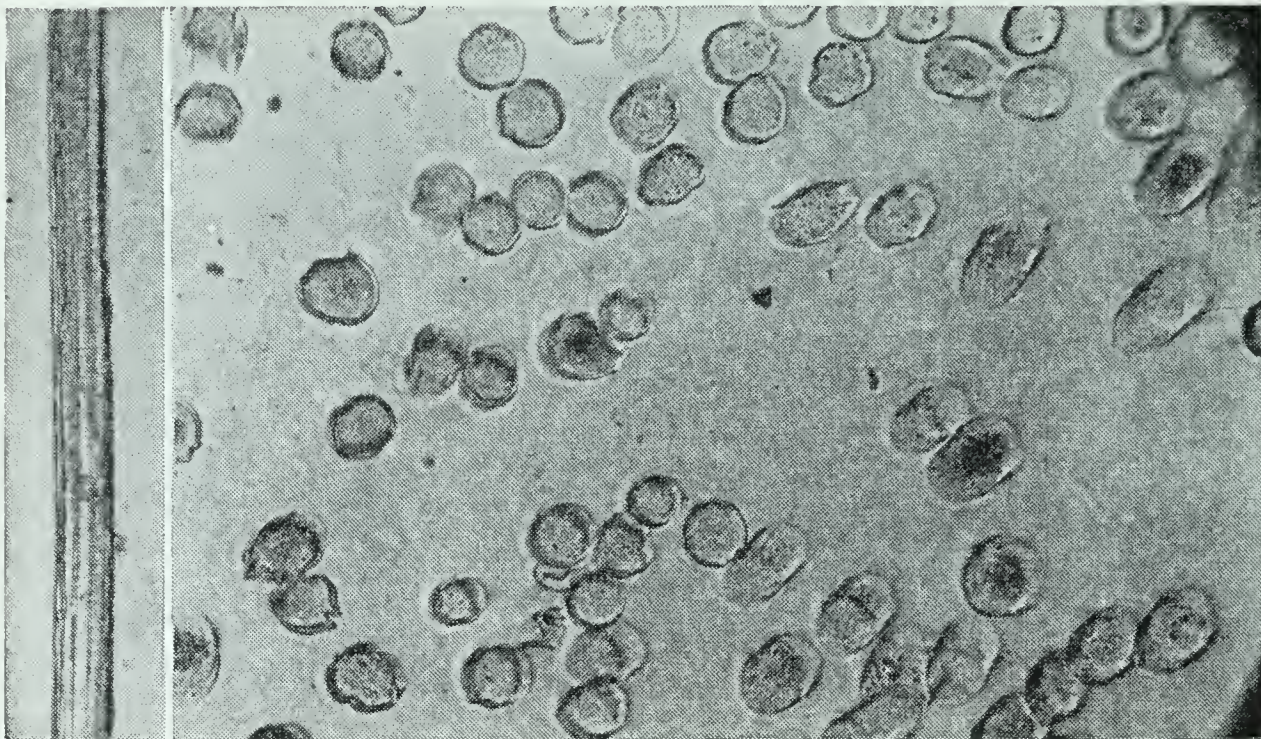
Microscopic appearance . . .	Longitudinal—striated Cross section—irregular surface
Size	40–2200 denier for filament; 1–25 denier for staple fiber
Tensile strength	Regular—1.5 to 2 grams per denier at 65% r. h.; 0.7 to 1.0 grams per denier wet
Elongation at break	15 to 30%
Standard regain	11%
Hygroscopy	27%
Effect of heat	Loses strength above 300° F.
Effect of sunlight	Causes loss of strength
Effect of acids	Concentrated acids destroy it
Effect of alkalis	Causes loss in strength
Resistant to moths	Yes
Resistant to mildew	No

CHARACTERISTICS OF CELLULOSE ACETATE FIBERS

Microscopic appearance . . .	Longitudinal—rodlike with one or two striations Cross section—two-, three-, or four-lobed
Size	30–300 denier for filament yarn 1–20 denier for staple fiber
Tensile strength	1.5 grams per denier 0.8 to 0.9 grams per denier wet
Luster	Bright and dull
Elongation at break	Regular—25%
Regain	6.5%
Hygroscopy	15%
Effect of heat	Thermoplastic—loses strength above 250 degrees F.
Effect of sunlight	Slight
Effect of acids	Concentrated solutions of strong acids destroy; weak acids do not injure
Effect of alkalies	Strong alkalies destroy; weak alkalies do not injure
Resistant to moths	Yes
Resistant to mildew	Yes

CHARACTERISTICS OF CUPRAMMONIUM FIBERS

Microscopic appearance . . .	Longitudinal—rodlike without markings Cross section—irregular; varies in size and shape
Size	30–300 denier for filament yarns
Tensile strength	1.5 to 2.5 grams per denier
Elongation at break	10 to 17%
Standard regain	11%
Hygroscopy	25%
Effect of heat	Decomposes at 300 degrees F.
Effect of sunlight	Causes loss of strength
Effect of acids	Destroys
Effect of alkalies	Resistant
Resistant to moths	Yes
Resistant to mildew	No



Photomicrographs of Lanital, in longitudinal and cross sections.

permits the production of a two-tone effect in piece-dyeing. These new fibers possess a greater affinity for direct cotton and other dyestuffs than do cotton or rayon. This permits the production of stripes or designs by piece-dyeing fabrics of the correct combination of fibers. Two-tone color effects are possible by combining Rayolanda X with wool because, although they have similar dyeing qualities, the wool has a greater affinity for the acid dyestuffs.

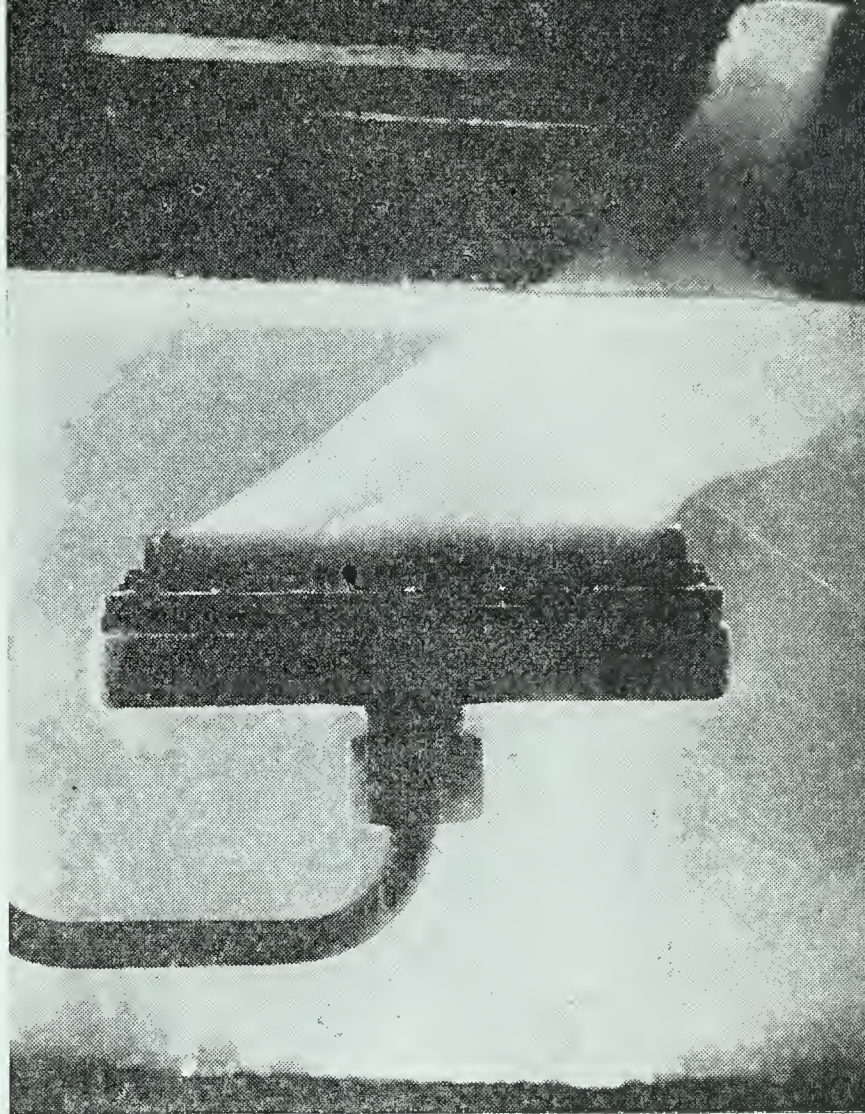
PROBLEM 5. WHAT SYNTHETIC PROTEIN FIBERS ARE BEING PRODUCED?

Casein azlon fibers. The most important synthetic fiber made from a protein base is the casein fiber for which the casein of skimmed milk is the raw material. The first fiber of this type was made in Italy and is known as Lanital. (See page 370.) Fibers made by practically the same methods are now being produced in many countries; thus, Lanital is produced in Italy, Tiolan in Germany, Polan in Poland, Cargau in Belgium, Casolana and Lactofil in Holland, Courtauld's casein fiber in England, and Aralac in the United States. The

manufacture of casein fiber is quite similar to that of viscose but differs in detail, the raw material in this case being casein from skimmed milk. The casein is dissolved in an alkali and coagulated in an acid bath. In the spinning of the viscose filament a solution of cellulose is forced through the spinnerette into a coagulating bath. The cellulose filaments are stretched during their spinning and are packed tightly in the form of a cake. It is not possible to stretch the casein filaments during spinning because they are so weak at this point that they must be allowed to fall loosely into the pot and be permitted to harden in a weak solution of formaldehyde for a few minutes. Following this hardening treatment they are drawn and stretched. In this process the spherical particles are changed to long particles. In spinning, orientation takes place and the elongated particles tend to assume a parallel position.

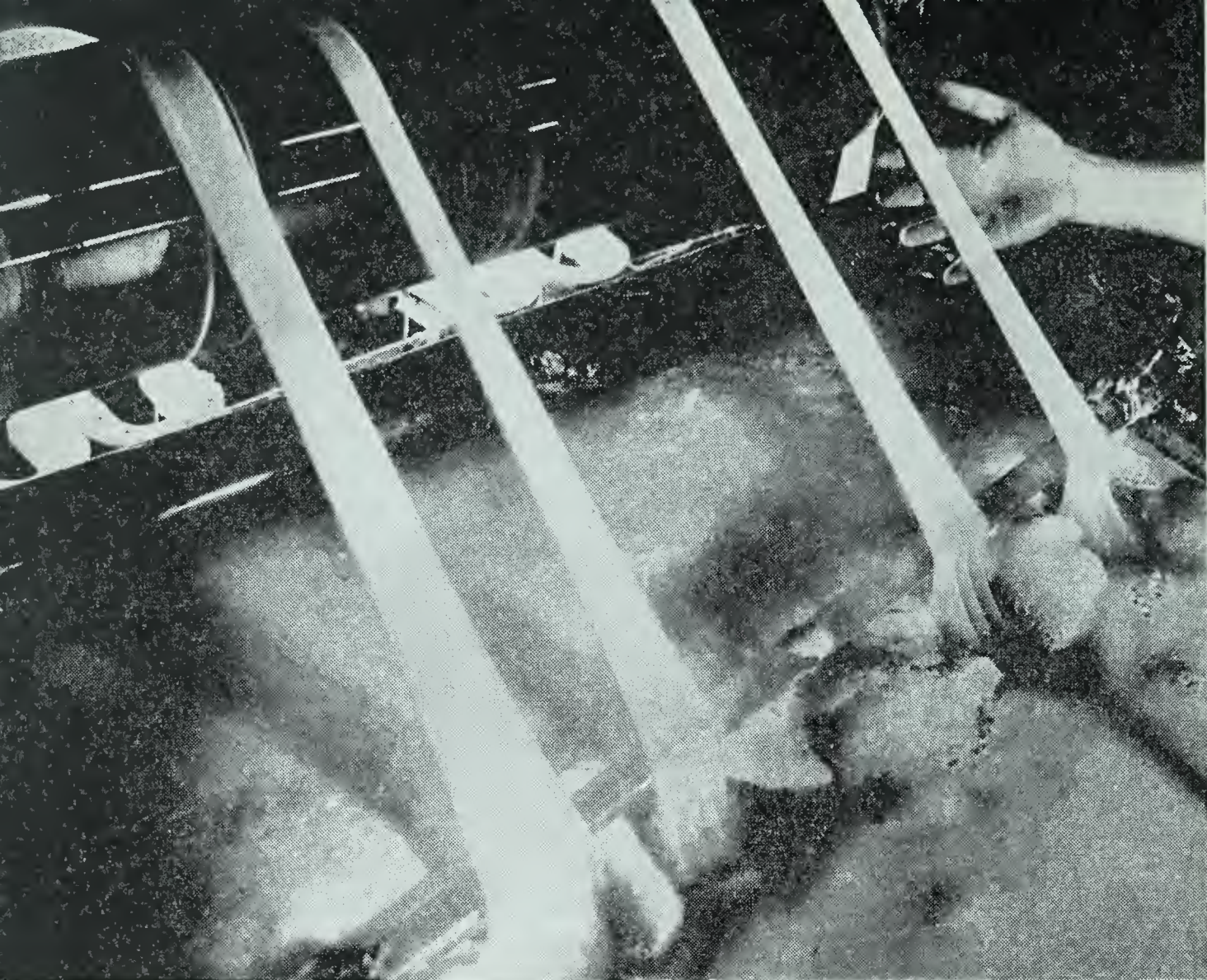
The casein fiber produced in the United States, under the name of Aralac, was first prepared for use with rabbit fur in the production of felt hats. The physical properties of this fiber differ slightly from those required for the production of knitted or woven fabrics. Mixing Aralac with rabbit fur increases the felting property and reduces the cost of the felt.

Casein fibers have the advantage of all man-made fibers—that of uniformity of length and size—and they are produced in a clean form suitable for use. The addition of casein fibers to the wool seems to be an aid in felting, especially in the



Courtesy Aralac, Inc., Taftsville, Conn.

Spinnerette in action. Aralac fiber as it comes out of the spinnerette. Liquid enters pipe at lower left and is forced through the thousands of holes in the spinnerettes.



Courtesy Aralac, Inc., Taftsville, Conn.

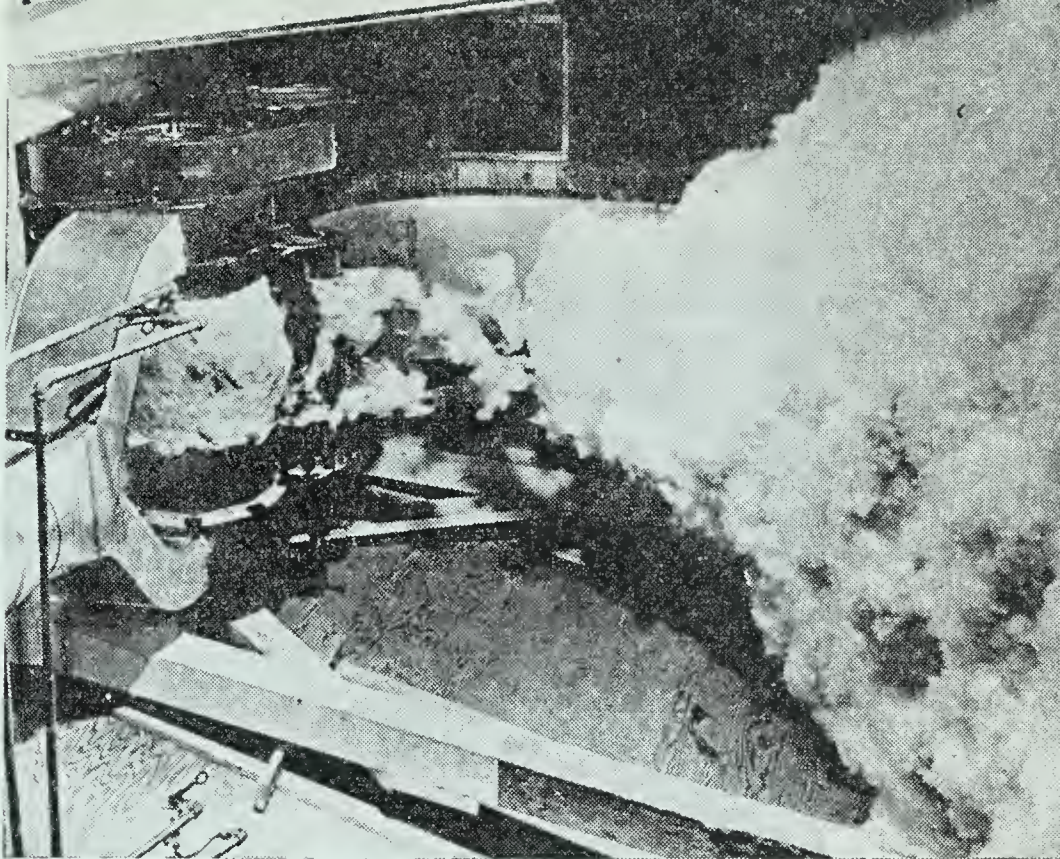
Spinning box. Concealed under the foam are four spinnerettes.

manufacture of hats. These fibers lack the physical and chemical properties necessary for true felting. In their production there are no disulfide cross-linkage groups formed, such as are held by some to be responsible for the felting action of wool. A pseudofelting results as water causes the surface of the casein fibers to soften and to adhere together if pressure is used. Constitutionally casein has a strong similarity to wool. It is a phospho-protein built up from a number of amino acids with a low sulfur content. It has a specific gravity of 1.26 as compared with 1.30 for wool and 1.5 for cellulose. It is warm to the touch, less inflammable than cellulose, and has a moisture regain similar to that of wool.

Some difficulties were encountered in the dyeing of casein fibers mixed with wool. Solid shades on wool and casein mixed goods are difficult to produce. Colors on casein fibers are not particularly fast to washing. The light fastness of dyes on these fibers is about equal to that of the same dyes on other fibers.

Mixtures of casein fibers and wool can readily be given a two-tone effect because the casein fiber dyes more rapidly and at a lower temperature than wool.

Casein fibers lack elasticity, strength, and stretch, especially when wet. The strength of casein fibers has been improved until it is only slightly lower than that of wool. The fiber is practically nonshrinkable but is attacked by insect pests. In their present state of



Courtesy Aralac, Inc., Taftsville, Conn.

Finished fiber. From the revolving drum at the top, cut and finished "Aralac" fibers drop down, ready to be baled and shipped to textile mills and other users.

CHARACTERISTICS OF ARALAC FIBERS

Microscopic appearance . . .	Longitudinal—faintly striated and granular
	Cross section—similar to wool
Diameter	25 microns
Tensile strength	1.0 grams per denier dry
Elongation at break	50% dry
Standard regain	13%
Hygroscopy	25%
Effect of heat	Affected at 212 degrees F.
Effect of sunlight	Similar to wool
Effect of moisture	Weakened
Effect of acids	Decomposed by strong acids; resistant to weak acids
Effect of alkalies	Affected by hot or strong alkalies
Resistant to moths	Attacked if not treated, but usually made resistant
Resistant to carpet beetles .	No
Resistant to mildew	Protected

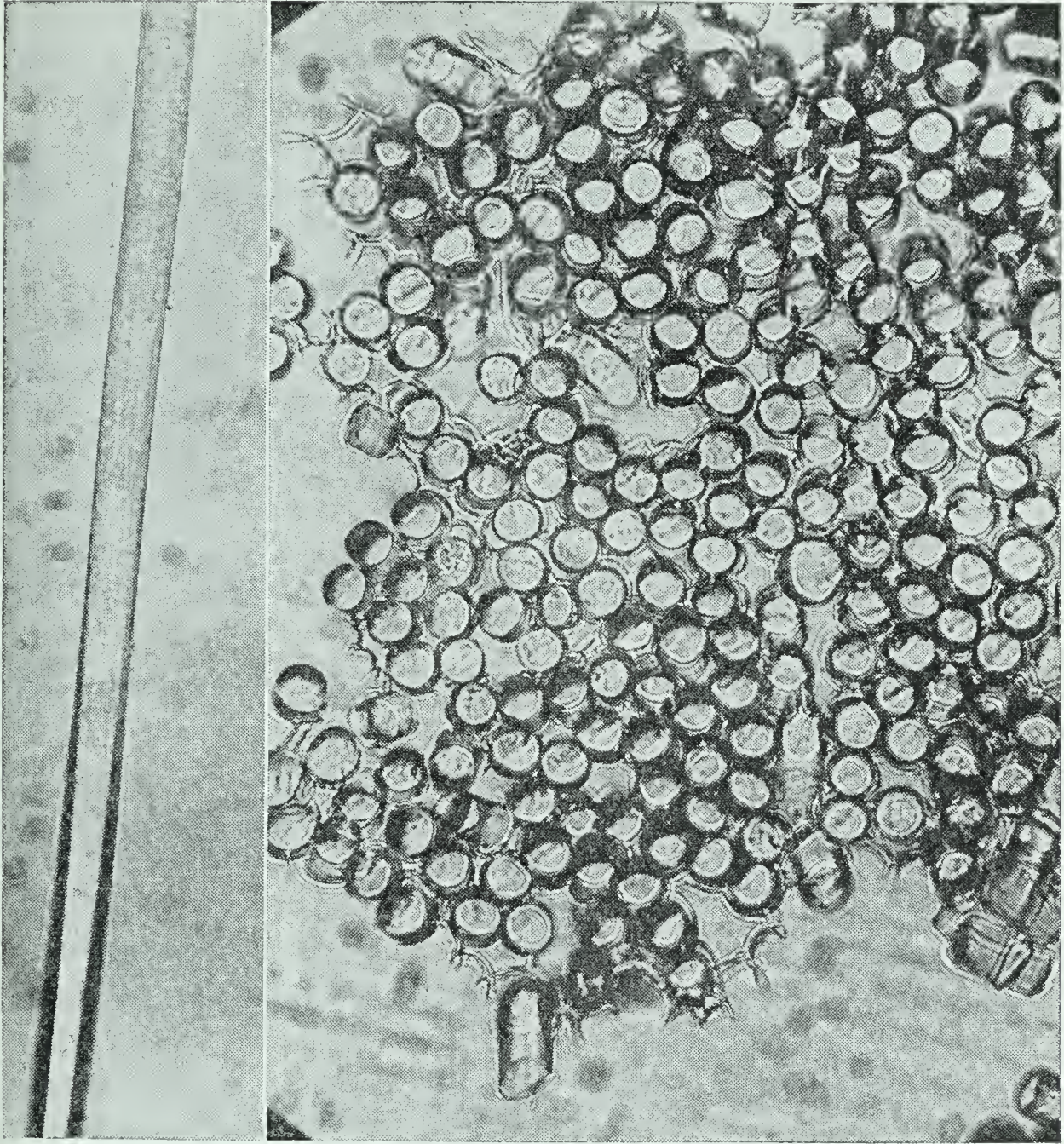
development casein fibers cannot compete with wool except in countries where wool is not available. However, some authorities are of the opinion that the raw material of casein is suitable for the production of a satisfactory textile fiber and that future developments will be made. A new process has been developed whereby alkaline casein solutions can be dry spun and subsequently hardened with formaldehyde in the absence of water. By this method fibers have been produced of double the strength of ordinary casein fibers.

The casein fiber is nearly circular in cross sections with an average diameter of 20, 25, and 30 microns. (See page 370.) Fine fibers of 16 microns diameter have been produced experimentally. These are comparable to one and one-half denier rayon and are much finer than any wool obtainable. The fiber is sensitive to high temperatures, yellowing noticeably at 220 degrees F.

Soybean azlon fibers. Protein from a vegetable source has been successfully used in the production of a synthetic textile fiber, known as the soybean fiber. Soybeans can be grown in most countries and especially in the southern part of the United States.

The commercial production of a textile fiber from soybeans began in 1943. The raw material for this fiber is the meal that remains after the oil has been extracted from soybeans. The powderlike protein removed from the meal is liquefied and formed into a mass of the consistency of molasses. This liquid is forced through a spinnerette by processes similar to those used in the production of other synthetic fibers. The filaments are stretched and hardened during carefully controlled chemical treatments. These fibers are finally cut into desired lengths. (See page 375.) By varying the treatments the characteristics of the fibers can be altered.

The soybean staple fiber is similar in luster, touch, and crimp to a rayon staple fiber but it is light tan in color. Dry soya fiber is approximately 45 per cent weaker than wool of the same grade and the wet fiber is 76 per cent weaker than the corresponding wool fiber. This fiber is more resistant to alkali than the older type fiber. It requires approximately



Longitudinal and cross section of soybean fibers.

11 minutes to dissolve the fiber of soybean in a five per cent caustic soda solution. It is claimed that this fiber is as warm as wool, and is resilient and durable, but it lacks strength, especially when wet. It is suitable for blends with rayon or cotton but not with wool.

Ardil azlon. A British vegetable protein fiber produced from peanuts or ground nuts is called Ardil. It is a staple fiber which is similar to wool but does not shrink and is not attacked by moths. The protein is extracted with a dilute alkali and after being precipitated it is made into a spinning solu-

tion which is extruded through a spinnerette into a coagulating bath. Ardil staple fibers may be blended with wool, cotton, or rayon. The yarns can be spun on the worsted, woollen, or cotton system according to the effect desired. Ardil fiber is cream colored, possesses a crimp, and is resilient. It is soft and warm to the touch, absorbs moisture in amounts similar to wool, and possesses properties which permit it to be molded under heat and pressure. This causes it to aid in the felting of wool when blended with it. With quantity production Ardil may be marketed at half the price of wool. Fabrics made with 50 per cent wool and 50 per cent Ardil have many of the characteristics of 100 per cent wool fabrics. When combined with cotton or rayon, Ardil adds warmth, crease resistance, and resilience, and gives the fabric a more wool-like texture.

Experiments have proved that fabrics of 100 per cent Ardil have poor resistance to abrasion. Actual wear tests have shown that blends of Ardil and viscose rayon staple have wearing properties equal to those of 100 per cent wool fabrics of similar structure. It is estimated that an all-Ardil and a blend of Ardil and wool have the same insulating value as an all-wool fabric of the same thickness and structure. The dyeing properties of Ardil are similar to the other protein fibers and the same types of dyes are used.

Zein azlon fibers. Another synthetic fiber from a protein base is known as *zein*. The material for this fiber is obtained from a gluten meal which is a by-product in the refining of corn for starches, dextrines, and sugars. In the production of zein fibers the gluten meal is first extracted with alcohol and then with toluol. In one method water is then slowly added to this mixture of zein, alcohol, water, and toluol while it is being agitated. This precipitates the zein as a doughy mass. Formaldehyde is also added in order to give satisfactory strength and water resistance to the fibers, and plasticizers are used to give softness and flexibility. This solution is then spun by a process similar to that used in the production of cellulose acetate—that of coagulating the fibers by extruding them into the air; or a liquid coagulant may be used.

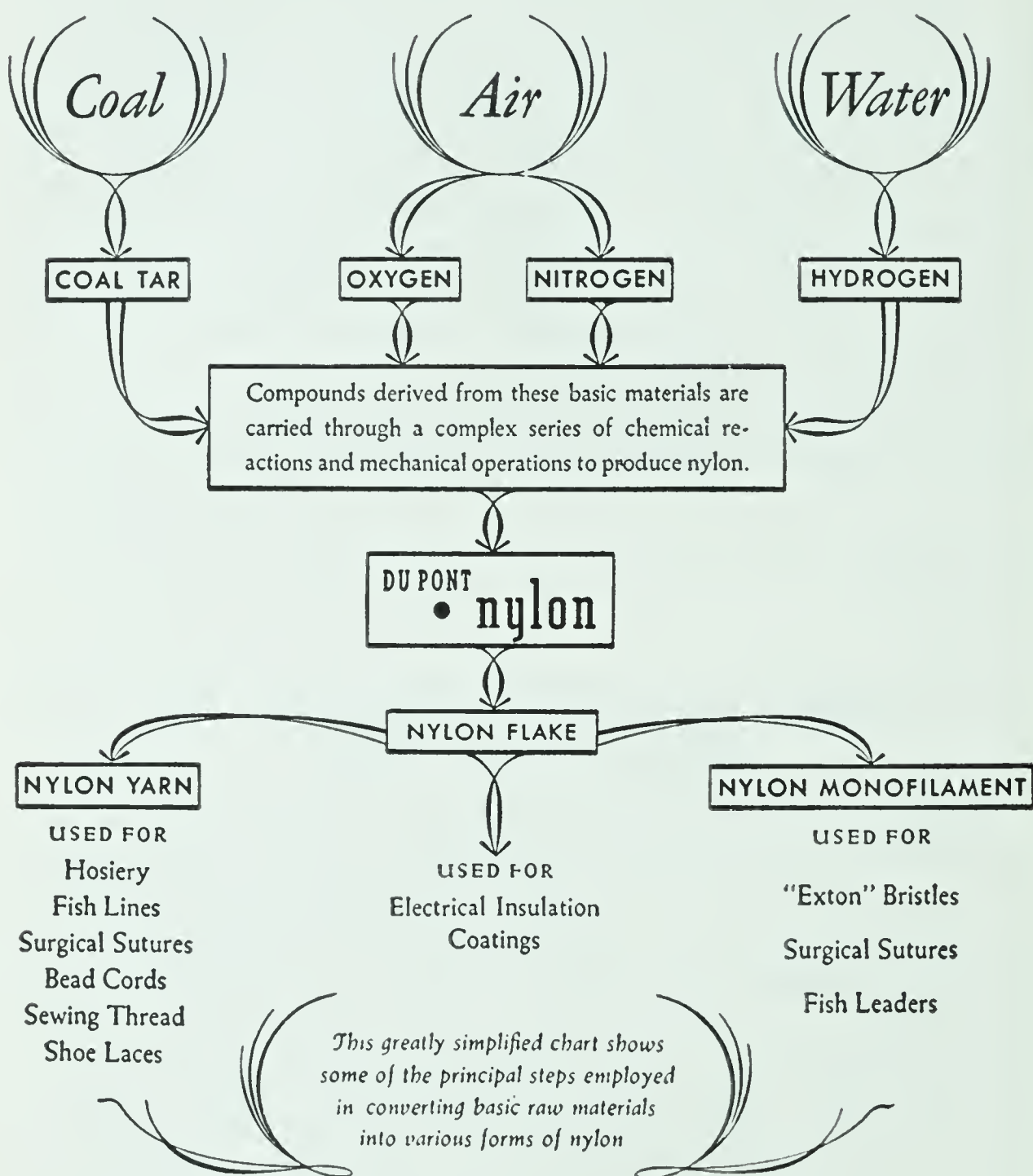
Satisfactory strength of the fibers is obtained by polymerization. This step is necessary before the fibers are wound and is accomplished by passing the fibers through a current of heated air. The temperature of the air must be maintained at between 60° and 90° C., as higher temperatures would cause decomposition. Five minutes is sufficient time for this preliminary treatment, and final polymerization is obtained by subjecting the fibers in a wound condition to these same temperatures for a period of from eight to ten hours. This process may be altered in various ways; but in all the methods the chemicals used are the same, and strength and water resistance are obtained in zein fibers by polymerization.

One advantage of using zein as a raw material for the production of fibers is that there is no refining process required; hence, the process is economical. It is claimed that the fibers are stronger and have more water resistance than do the normal rayons.

PROBLEM 6. OF WHAT IMPORTANCE ARE SYNTHETIC RESIN FIBERS?

Synthetic resins are one of the newer types of raw material utilized in the production of synthetic fibers of which nylon is the most important. Nylon has been designated as the wonder fiber because it can be prepared in so many forms and with such varied characteristics. The history of this fiber has its beginning in pure research started early in 1928 by Du Pont Company, with no thought of practical application. Its first efforts were directed toward a study of polymerization, which is the method by which large molecules are made from small molecules. From this study it was found that large molecules of great strength—linear super-polymers—could be produced. In removing a molten mass of long-chain super-polymers from the still, a research worker noticed that it could be drawn out into a long fiber. Even after the fiber was cold it could be further drawn. This led to research directed toward the synthesis of a super-polymer that, when drawn out, would possess the qualities which would permit it to be

Genealogy OF ONE TYPE OF NYLON



Courtesy E. I. DuPont de Nemours and Co.

Basic steps in the production of nylon.

used as a textile fiber. The fibers first produced lacked strength and elasticity, or they became soft at low temperatures or were affected by water. After much preliminary work a polyamide was found from which a fiber possessing the desired characteristics could be spun. In explanation it may be

said that a polyamide is a polymer containing a plurality of amide (NH_2NH) linkages. Much further research was required before the necessary raw material was discovered. The term nylon does not refer to the textile fiber but to the polyamide from which the fiber and also bristles and sheets can be made. These polyamides are formed by the synthetic reaction of di-basic acid with an organic diamine. By this reaction small molecules (amides) are formed. These are changed by heating into the giant molecules or super-polymers.

Because there are many di-basic acids and a corresponding large number of diamines which may be combined in different ways, it is possible to produce various forms of nylon each with different physical properties. This synthetic material is different from any existing natural product. In 1938 nylon was announced to the world as a group of synthetic superpolymers from which a textile fiber could be spun which surpassed any known fiber in strength and elasticity.

Nylon is a truly synthetic fiber which has had the most phenomenal acceptance of any fiber yet produced.

Nylon is officially and scientifically defined as "a man-made protein-like chemical product (polyamide) which may be formed into fibers, bristles, sheets, and other forms which are characterized when drawn by extreme toughness, elasticity and strength."



Courtesy E. I. DuPont de Nemours and Co.,
photo by Jesse E. Hartman

The birth of nylon filaments. From tiny holes in this spinnerette are extruded these fine filaments of nylon. All of the filaments shown here will be wound together to form nylon yarn.

The nylon used as a textile fiber is synthesized from products of bituminous coal, water, and air. In the process of manufacture phenol is produced from which a diacid and also a diamine are derived. The oxygen from the air is used in making the diacid, and ammonia, formed by the uniting of hydrogen from water with nitrogen from the air, aids in making the diamine. Thus the raw materials necessary for this fiber are bituminous coal, water, and air. (See page 378.)

In making nylon fiber, the molten mass of the polyamide is forced through fine orifices by means of a pressure head of nitrogen to yield filaments. The process is defined as high-temperature extrusion. The size of these filaments is determined by controlling the rate of delivery of the fluid to the spinnerette and the rate at which the filaments are drawn from the spinnerette. However, the standard yarn contains filaments approximately three denier in size. The filaments drawn from one spinnerette are wound together, the number of filaments in the yarn being dependent upon the number of holes in the spinnerette. (See the illustration on page 379.)

The long molecules of nylon lie in a helter-skelter position when it is made. The drawing of the cold fiber causes these chainlike molecules to be rearranged into a parallel position in which they are much closer together. The high strength and elasticity of nylon is dependent upon this property. The extreme strength of nylon is attributed in part to the fact that the molecules in the drawn fiber lie so close together that powerful inter-molecular forces are set up. The comparatively extreme length of the molecule chain also contributes to the strength of these fibers.

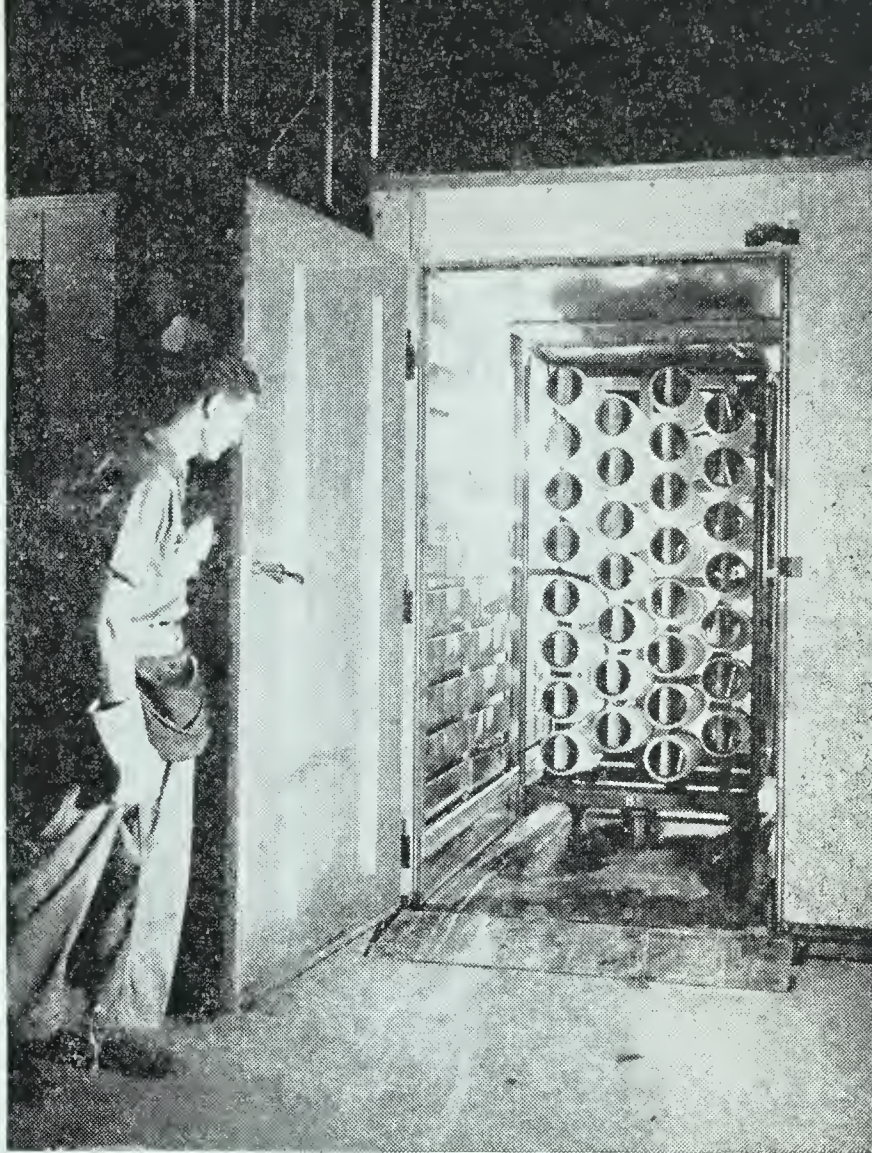
Nylon is inert in the presence of reducing agents. In general it resists oxidizing agents well. For most purposes bleaching is not necessary. Hypochlorites or peroxide have only a limited effect and the permanganate process is more effective if used in slightly higher concentration than is common for other fibers. Acids show no appreciable effect in the cold up to concentration of 5 per cent. Nylon is soluble in concentrated formic acid but not below concentration of 10 per cent. Acetic acid has no solvent or swelling action on nylon. The re-

sistance of nylon to alkali is indicated by the fact that treatment with 10 per cent caustic soda solution at 80° C. for ten hours causes a loss in strength of only 5 per cent.

The melting point of the nylon fibers constructed into fabrics is above that normally used in ironing, being as high as 480° F. Another advantage of the nylon textile fiber is that it will not blaze but melts when brought into contact with a flame. Water and the chemicals commonly used in dry cleaning have no injurious effects on nylon. Nylon fibers are easily wetted with water but they do not lose strength when wet and dry much more quickly than any other textile fiber. A permanent set is easily given to nylon fibers or yarns by treatment with steam or hot water. This method is used to give nylon hosiery their permanent shape.

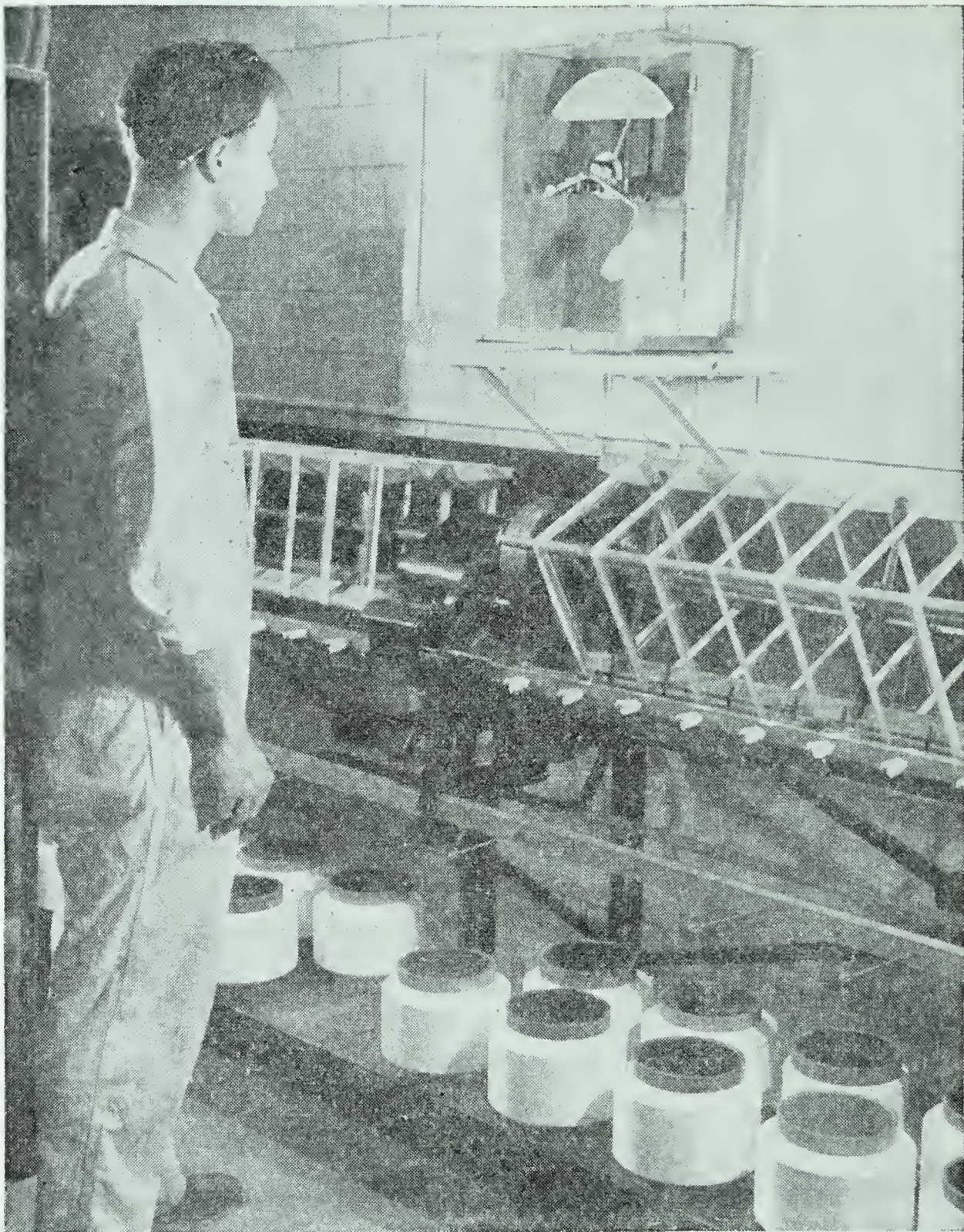
It is claimed that nylon fabrics are no more sensitive to exposure to light than other textiles and that they do not deteriorate during storage in the absence of light. This fiber is naturally not subject to mold or mildew, and sea water, heat and cold have no effect on it. Clothes moths do not attack nylon but various carpet beetles will feed on it.

Nylon fabrics do not present any particular problem with regard to either washing or ironing. They should be handled as all fine fabrics, in lukewarm, mild suds. The suds should be squeezed through the fabric and thoroughly removed by rinsing and the fabrics should not be put through a



Courtesy E. I. DuPont de Nemours and Co.,
photo by William M. Rittase

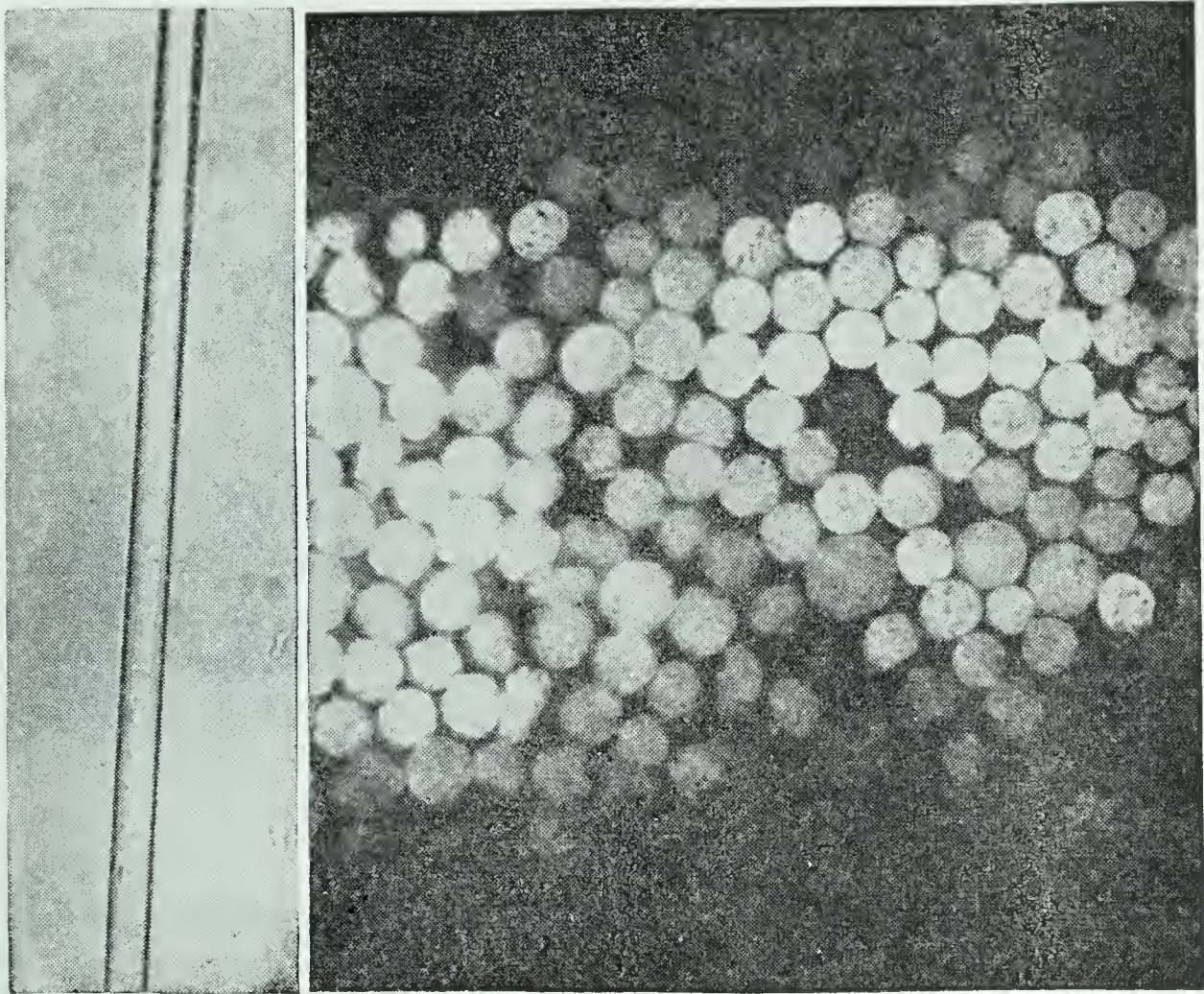
Nylon yarn is "baked" in large "twist setting ovens" like the one pictured.



Courtesy E. I. DuPont de Nemours and Co.

Nylon yarn is checked for weight. Samples of uniform length are taken from bobbins that come from the spinning machine and weighed to check the denier of the yarn.

wringer or twisted. Nylon fabrics dry quickly and many of them may be worn without ironing although a slight pressing on the wrong side usually improves their appearance. They



Courtesy Walter Krauss

Longitudinal and cross sections of nylon fibers.

may be ironed wet or dry and since wrinkles are easily removed from nylon a hot iron is not necessary. It is recommended by some authorities that a temperature of not more than 275° F. be used. Since nylon can withstand higher temperatures without injury the setting of 300° – 350° F. would be satisfactory.

The high strength and elasticity of nylon make it an ideal hosiery fiber. It is especially suited for all fabrics where lightness and low moisture content or quick drying are desired. The moisture regain for nylon is only 3.8 per cent, which is the lowest of all the textile fibers.

Nylon can be dyed with acid colors that possess affinity for silk, but more satisfactory results are obtained with dyes normally used on cellulose acetate rayon.

Neophil, a sewing thread, was the first textile product made

from nylon. This thread is characterized by high strength, elasticity, fineness, and uniformity. It does not lose these properties when laundered. Neophil is being supplied in a wide variety of colors and sizes.

The development of nylon staple fiber, interrupted by the war but now in progress, may enable the manufacturers to greatly improve the quality of their product and broaden the field for its use. A study of the utilization of continuous filament waste was continued during the war on a military basis. From this work it has been learned that from 10 to 20 per cent of nylon blended with other fibers adds strength far out of proportion to the amount of nylon used. These small percentages may permit spinners to make finer yarns more economically than has yet been possible. Larger percentages of nylon blended with other fibers add many desirable characteristics. Hosiery made from these blends may resist shrinking, minimize darning, and dry quickly. The one hundred per cent spun nylon yarns have all the desirable qualities of the continuous filament yarn and possess a cushioning effect that is most desirable in hosiery.

CHARACTERISTICS OF NYLON FIBERS

Microscopic appearance . . .	Cross section—approaches circular
Tensile strength	4 to 8 grams per denier
Diameter	10 microns—several hundred
Elongation at break	20% to 25%
Standard regain	5%
Hygroscopy	4%
Effect of heat	Melts at 480° F.
Effect of sunlight	Decreases strength
Effect of acids	Resistant to both high and low concentrations
Effect of alkalis	Highly resistant
Resistant to moths	Yes
Resistant to various carpet beetles	No
Resistant to mildew	Yes

Vinyon. Vinyon, another resin fiber, is a co-polymer of vinyl chloride ($C_2H_3Cl_1$) and vinyl acetate ($C_4H_6O_2$) pro-

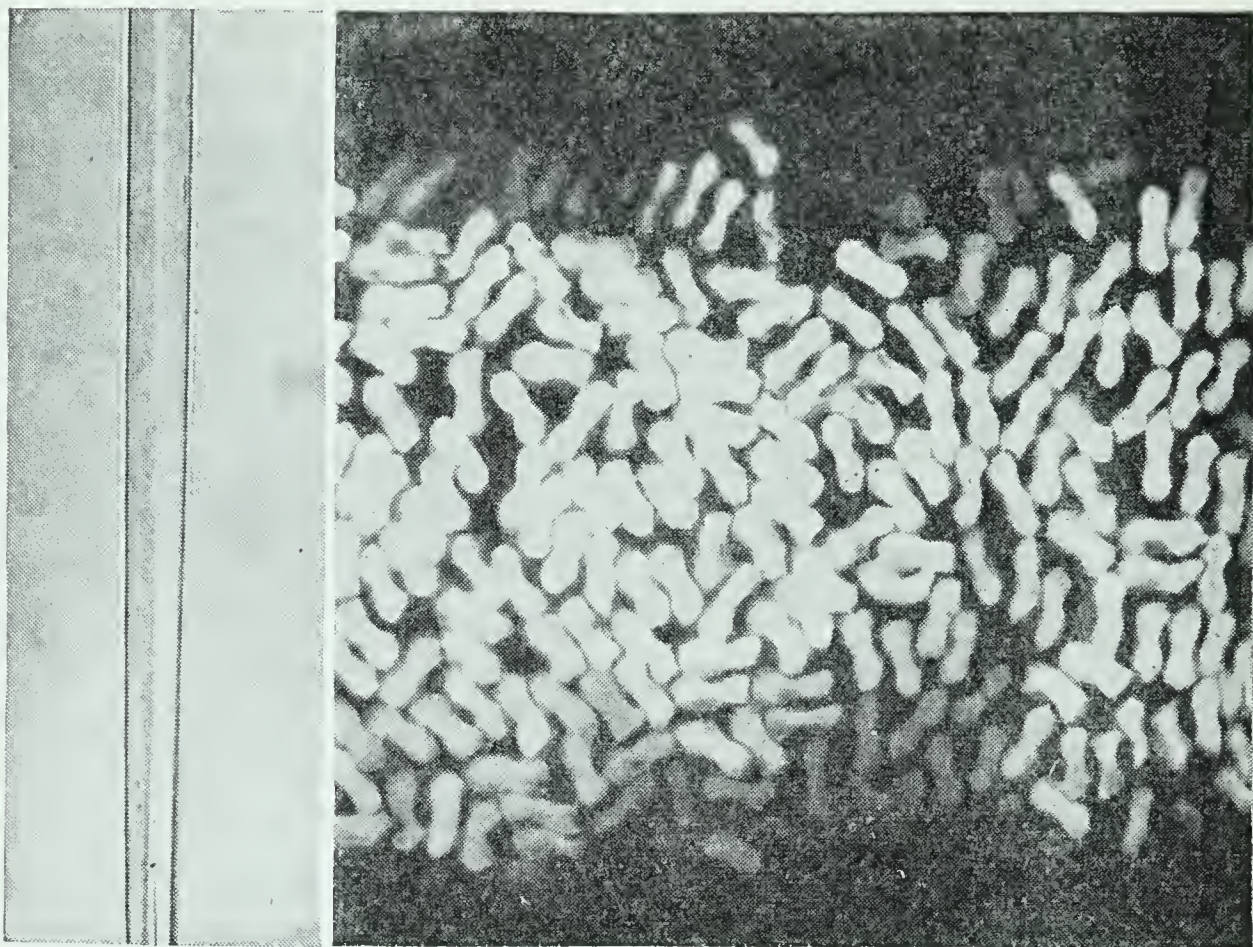
duced by polymerization. The result of this combination is a straight chain or linear co-polymer of great length, and consequently great molecular weight, the two characteristics that seem to bear most directly upon the strength and resilience of the vinyon fiber.

Vinyon was the first all-resin fiber to be produced. (See page 386.) It appeared on the market in 1938. In making the multifilament yarns of vinyon the raw co-polymer of vinyl chloride and vinyl acetate in the form of a white powder is dispersed in acetone to obtain a mixture containing 23 per cent of the polymer by weight. After filtering and de-aerating, the dispersion is spun by a dry- or air-spinning process, the same as cellulose acetate.

The filaments are allowed to stand at least twelve hours on the take-up bobbin, after which they are spun. After spinning the fibers are stretched at least 140 per cent of their original length. As a result of this stretching process the fibers possess a high breaking strength and true elasticity. A setting process is next required. The dry breaking strength of a vinyon yarn is 3.4 grams per denier and the elongation is 11 per cent with an elasticity equal to silk. Vinyon is waterproof and water-repellent and will not support combustion. It has natural crease resistance. It is unaffected by alkali or mineral acids, and alcohols, gasoline, and most other types of solvents. This resistance to chemicals is one of its outstanding properties.

The yarn can be delustered by the use of pigments added to the spinning solution or by treatment with hot water. Dyeing can be accomplished with acetate dyes. The yarns can be knitted, braided, or woven on the ordinary types of textile machinery.

The one property of this fiber that prevents its ready acceptance as a fiber for use in clothing or household fabrics is its high thermoplasticity. It starts to soften at temperatures much less than 100°C . This makes dyeing difficult and hot pressing impossible. This very characteristic, however, makes vinyon fibers suitable for molding. A mixture of 15 to 20 per cent vinyon with cotton produces satisfactory cloth which is finding commercial use as a substitute for felt.



Courtesy Walter Krauss

Longitudinal and cross sections of vinyon ($230\times$). Notice the peculiar shape of the cross section.

Vinyon blended with wool, cotton, or rayon may be woven into a material that will hold the shape into which it has been pressed. It will have use wherever waterproofing and acid and alkali resisting qualities are desired. Vinyon yarn ranges in price from \$1.35 to \$1.45 per pound.

In 1942 Vinyon E. was placed on the market. This fiber is characterized by extreme elasticity. For some purposes it has been found superior to rubber as it resists sunlight, heat, and humidity and is unaffected by acids. It will find wide application in the production of such articles as girdles, brassieres, and surgical stockings.

Saran, Velon, or Permalon. These three names apply to a fiber that chemically is a vinylidene chloride resin derived from ethylene, a product of petroleum and chlorine. By controlling the polymerization, or linking of molecules, a plastic

material ranging from flexible and soluble kinds to hard, tough, and insoluble ones may be produced. Window screening and upholstering material are two fields for which this mono-filament fiber seems to be especially suited. Saran or Velon resists corrosion, salt water, and other climatic conditions better than bronze, and has a high wet and dry strength. Upholstering materials made from this plastic are stainless, resist acids and alkalies, and are noninflammable, outlasting the article on which they are used. The high flexibility of Saran filaments makes them peculiarly suitable for use in insect screening.

CHARACTERISTICS OF VINYON FIBERS

Microscopic appearance . . .	Cross section—rounded ends and flattened in center
Diameter	12.5 denier
Tensile strength	1–4 grams per denier dry and wet
Elongation of break	30 to 35% dry and wet
Standard regain	Less than 1% .
Hygroscopy	0.1%
Effect of heat	Melts at 260 degrees F.
Effect of sunlight	None
Effect of acids	None
Effect of alkalies	None
Resistant to moths	Yes
Resistant to mildew	Yes

PROBLEM 7. OF WHAT IMPORTANCE ARE OTHER SYNTHETIC FIBERS AND YARNS?

Alginate fibers. The production of alginate fibers from a seaweed base is in general the same as the production of rayon. Seaweed contains alginic acid, a highly glutinous substance rather closely related in chemical structure to pectic acid and cellulose. If a solution of sodium alginate is extruded through a spinnerette and drawn through a dilute acid, alginic acid is regenerated in the form of fibers. Alginic acid and the simple alginates are soluble in soap and soda solutions. To overcome

this lack of resistance to alkalies the fibers are treated with solutions of alum-beryllium salts. By this process the fibers are changed to aluminum and beryllium alginates which are comparatively resistant to soaps and alkalies.

All alginate fibers are noninflammable. The number of possible yarns is limited only by those metals which give insoluble salts with alginic acid without discoloration. Yarns having a breaking strength of 2.00 grams per denier per filament have been produced.

There are great possibilities for the future use of these yarns as a "carrier" thread for producing extremely fine fabrics. Fine single worsted and woolen yarns too fine to withstand weaving can be carried along with the alginate yarn which is afterward dissolved from the fabric. Another possibility suggested is the wrapping of a thermoplastic yarn such as nylon around a central thread of alginate which is removed after the thermoplastic yarn has been set. Wool has been used in this way also. Fabrics with interesting corrugated surfaces and even pile effects may be produced by the use of such yarns. While the wool is curled around the alginate yarn it can be woven and then set by steam. After the soluble alginate yarn has been removed, a crimped effect remains. Openwork effects may be obtained by weaving soluble alginate yarns in stripes or checks with wool and dissolving out the alginate.

The soluble property of the alginate yarn presents unlimited possibilities in the development of new fabrics and new designs. Further development of the uses of these unusual yarns will result in the production of a wider range of dyes and improved application methods. Although it has been found difficult to dye these yarns there are available a sufficient number of dyestuffs which can be used to give a wide range of colors satisfactorily fast to light and washing.

Plastics. Plastics in sheet form, resin-coated yarns, and rubber are used in various amounts in clothing and household fabrics. The distinction made by one authority between a fiber, a plastic, and rubber is based upon its ability to crystallize. Chainlike molecules that fit well into a lattice will crystallize and be fiberlike. If the forces between the chains are

high, the substance exhibits the properties of a fiber. Those exhibiting very weak forces between chains are rubbery. Those with forces of intermediate strength are plastics.

Plastics in sheet form are being made into rain coats, pocket books, traveling bags, shower curtains, and many other peacetime articles.

The properties of the coated yarns are determined by the resins used. They vary from stiff to flexible and from inflammable to self-extinguishing. The tensile strength of all of them is generally good and their resistance to chemicals can be controlled. Resin-coated yarns of various fibers find wide use in fabrics for shoes, handbags, upholstering, and accessories of all types.

Synthetic rubber is extruded in round yarns, or sheets are cut into narrow strips which serve as yarns. Rubber yarns vary greatly in tensile strength but have great elongation and 100 per cent elastic recovery. They do not absorb moisture and are highly resistant to heat. They form the core for covered yarns used in a wide variety of fabrics which are made into foundation garments, suspenders, garters, and many other similar articles.

Paper fibers. Cords and yarn made of paper have been in use for many years in certain countries. The manufacture of yarns and fabrics made from paper developed rapidly during World War I in countries where there was a scarcity of textile fibers. It was during this time that paper yarns began to be used in England and France in the construction of Wilton rugs. In the United States paper yarns have been used for many years in imitation cane for furniture. Today, paper twines and fabrics have many uses. In the production of paper fibers or yarns, sheets of paper are slit to a width determined by the size and strength of yarn desired. These strips are then moistened and twisted by machinery.

Paper cords may be pressed or shaped into triangles, rectangles or ovals. If color has been added when the paper is made, fibers can be produced that are fast to sunlight and will not bleed. A recent development is the addition of resins to the pulp mixture to increase the wet strength of the finished

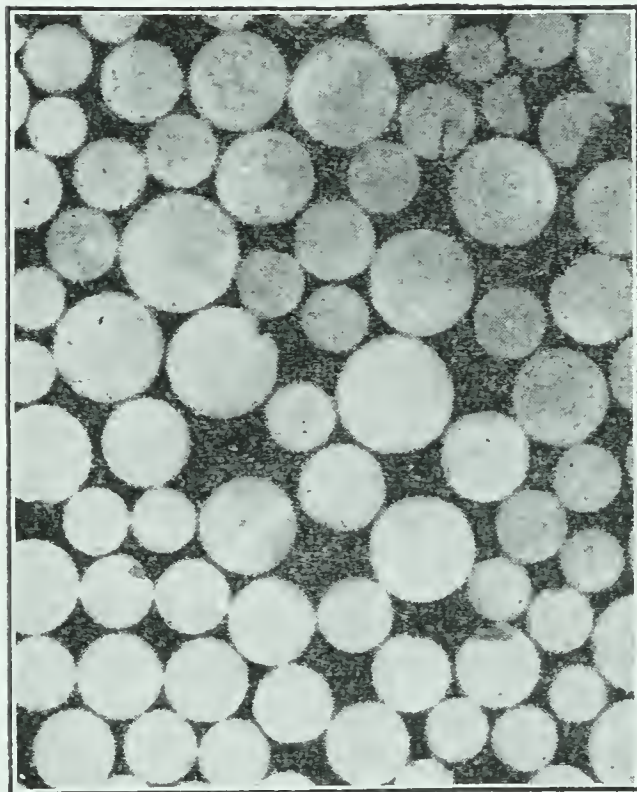
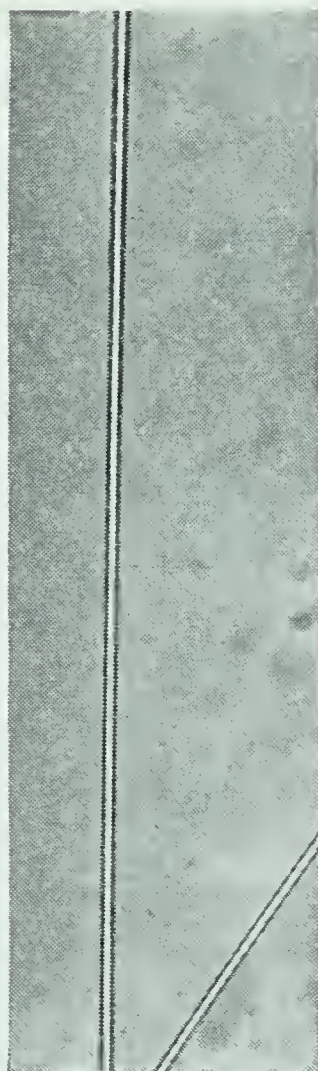
yarn. Paper yarns have found wide use in the electrical field as wrapping for wires. The automobile and luggage industries have found many places where paper cords are more satisfactory than any other type.

Recent government specifications for rugs and carpets include paper yarns, since the use of jute yarn for this purpose was forbidden during the recent war. The paper yarn may be used as stuffer warp in Wilton and Velvet rugs and as filling in Axminster rugs. Paper yarns will no doubt find a permanent place in rug manufacture; although they have some disadvantages, the wet strength can be controlled and held to a high percentage of the dry strength.

PROBLEM 8. OF WHAT IMPORTANCE ARE GLASS AND METAL FIBERS?

Glass fibers. Although glass fibers have been produced for many years and used to a limited extent in the manufacture of textile fabrics, not until the development of *Fiberglas* have they possessed properties which made them a potential textile material. The continuous filament and the staple fiber processes are the two used in their production. In the continuous filament process glass marbles are fed into an electrically heated furnace. The molten glass is drawn down by gravity and emerges as tiny filaments from 102 holes. This group of filaments is combined to form a strand and wound onto a winder. The rapidly moving winder draws the fibers to a fraction of the diameter of the holes through which they flowed. With the development of the noncontinuous or staple process, finer and more pliable filaments were made possible. Glass marbles are used in this process also which begins in the same way as the other but in which the molten glass is caught by high pressure steam and drawn forcefully into fibers ranging in length from 8 to 12 inches.

Fiberglas is extremely strong and can be twisted, plied, and woven on standard textile machinery. The tensile strength of Fiberglas is approximately 300,000 pounds per square inch and the average diameter is from 22 to 38 one-hundred thou-



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Longitudinal and cross sections of glass fibers.

sandths of an inch. Fiberglas is completely incombustible, nonhygroscopic and nonabsorbent, and the fibers do not swell, stretch, or shrink. They are resistant to mildew and rot, and moths or other pests cannot eat them. They are unaffected by weak alkalies or acids in any form with the exception of hydrofluoric and phosphoric. Probably the greatest potential field for the use of Fiberglas is in that of decorative fabrics; however, they are not suited for use as upholstery fabrics or other places where they would be subjected to friction.

CHARACTERISTICS OF FIBERGLAS

Microscopic appearance . . .	Longitudinal—rodlike
	Cross section—circular
Tensile strength	6.3 to 7 grams per denier dry
	and wet

CHARACTERISTICS OF FIBERGLASS (Continued)

Elasticity	2 to 4%
Standard regain	None
Hygroscopy	Less than 0.1%
Effect of heat	No effect except at extremely high temperatures
Effect of sunlight	None
Resistant to moths	Yes
Resistant to mildew	Yes
Effect of acids	Attacked only by hydrofluoric and phosphoric acids
Effect of alkalies	Destroyed by hot solutions of weak alkalies and cold solu- tions of strong alkalies

Metal fibers. Metal fibers are of more or less importance in the textile industry, depending upon the vogue. Metallic yarns find their greatest use in decorative fabrics such as tapestries, and in braids and fringes. Gold, silver, copper, and various alloys, drawn out into fine filaments, may be used by themselves but are more often found as a coating for a fiber of other metal or of cotton or linen. Finely divided particles of metals may be held in suspension in a cellulose acetate solution and used as a coating for yarns made from vegetable fibers. Yarns may be coated with different adhesive substances holding in solution a metallic powder. Made in this manner the yarn easily loses the metallic effect. However, at certain times they are used to produce novel effects in clothing fabrics planned especially for formal wear.

Aluminum fiber. Aluminum fiber is a recent addition to our metal group. It is not spun from a molten mass but is cut into strips from large rolled sheets. Reymet and Reyspun are the names given to two types of these yarns already being manufactured. Reymet is pure aluminum but Reyspun is coated on both sides of the strip with cellulose acetate. This coating not only adds tensile strength but permits the addition of any desired color. These metallic yarns are too heavy to be used successfully alone but will furnish decorative yarns for fabrics woven from yarns of other fibers. They are washable, not affected by the elements, will not tarnish, and can be

dry-cleaned. The use of these fibers in blends of other fibers is a future possibility.

Suggestions for the Laboratory

Study high power magnifications of mounted specimens of the different synthetic fibers.

Compare the physical and chemical properties of these fibers. How would their properties influence the selection, use, and care of fabrics made from them?

Compare the price, texture, and general appearance of available fabrics suitable for household and clothing use.

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Section Three

TEXTILES AND THE CONSUMER



Unit One

THE CONSUMER AND THE TEXTILE MARKET

THE laws of supply and demand are the most potent factors in the textile market. If the textile industry is to flourish in any geographic area, not only must the raw material be available this year at a fair price, but its continued availability for a period of years must be assured. Nearness of the mills to the source of supply, tariff on imported material, both raw and manufactured, all influence the production and distribution of textiles.

When the production of a textile fiber is limited, as in the opening of the wool industry in a given state, shipment to mills in faraway places follows as a matter of course. The production is not great enough to warrant the capital investment necessary for a manufacturing plant. Later, when the production increases in volume, the amount spent for transportation becomes great enough to challenge interest in continuing the manufacturing processes nearer the center of production. Such developments may come rapidly because war conditions cause a country to become increasingly dependent on the domestic supply of wool, thus speeding up local production.

The tariff or customs duty is a tax imposed upon those who bring goods across the frontier, the basis of the tax being the quality and kind of the goods moved. Originally tariff was devised to secure revenue, but later public interest in tariff for revenue was largely overshadowed by interest in tariff for protection. The precedent back of protective tariff was the promulgation of prohibitions that make illegal the introduction

into the markets of a country competing goods from outside sources. Textile history is filled with many interesting examples of attempts to alter consumption trends through prohibitions. In one instance during the middle of the seventeenth century, the French manufacturers of silk and wool sought by stringent laws which were actually passed to protect their markets from the invasion of the printed and painted calicoes and chintzes of India.

Protective tariff is in force today on most textiles used for clothing and household purposes. However, the advantages of a controlled market are not clear to the consumer at present. There is no protection today concurrent with the duty that insists on home production in the form of stipulations concerning the quality of fabric produced; or even concerning labels, giving the quality and kind of yarns used and the amount of sizing of each piece of the finished goods; nor is there any supervision provided to enforce these stipulations.

We are told that there is an evident trend to subordinate the advantages heretofore afforded specific American industries, such as textiles, to the broad interests concerned with the achievement of a greater measure of international solidarity and peace. There is little likelihood, however, that the existing tariffs and other barriers affecting international trade will be wholly removed in the near future. The most that can be expected is a gradual reduction made in successive steps. Whether the fabric is produced at home or abroad, informative labeling is necessary for intelligent consumer use.

PROBLEM 1. WHAT INFLUENCES THE CONSUMPTION OF TEXTILES?

Mode of living. The consumption of textiles in any country is largely determined by the culture or mode of living. The felt needs of a people depend upon their point of view, their attitude, and their general way of living. Some of the natives of Africa, for example, go without clothing, feeling no need for articles of apparel. The inhabitants of certain Cen-

tral American countries go without shoes, feeling no need for them. Draperies and window curtains played no part in the life of the American Indian, as he felt no need for these articles. To a marked extent one need already felt or one interest already established may be expanded through associations to include a complex list that will markedly increase consumption along these lines. A need once met with curtains may be extended so as to require glass curtains, draperies, and shades. The black silk dress for Sunday best of great-grandmother's day met a need that today requires a wardrobe of numerous garments and many accessories.

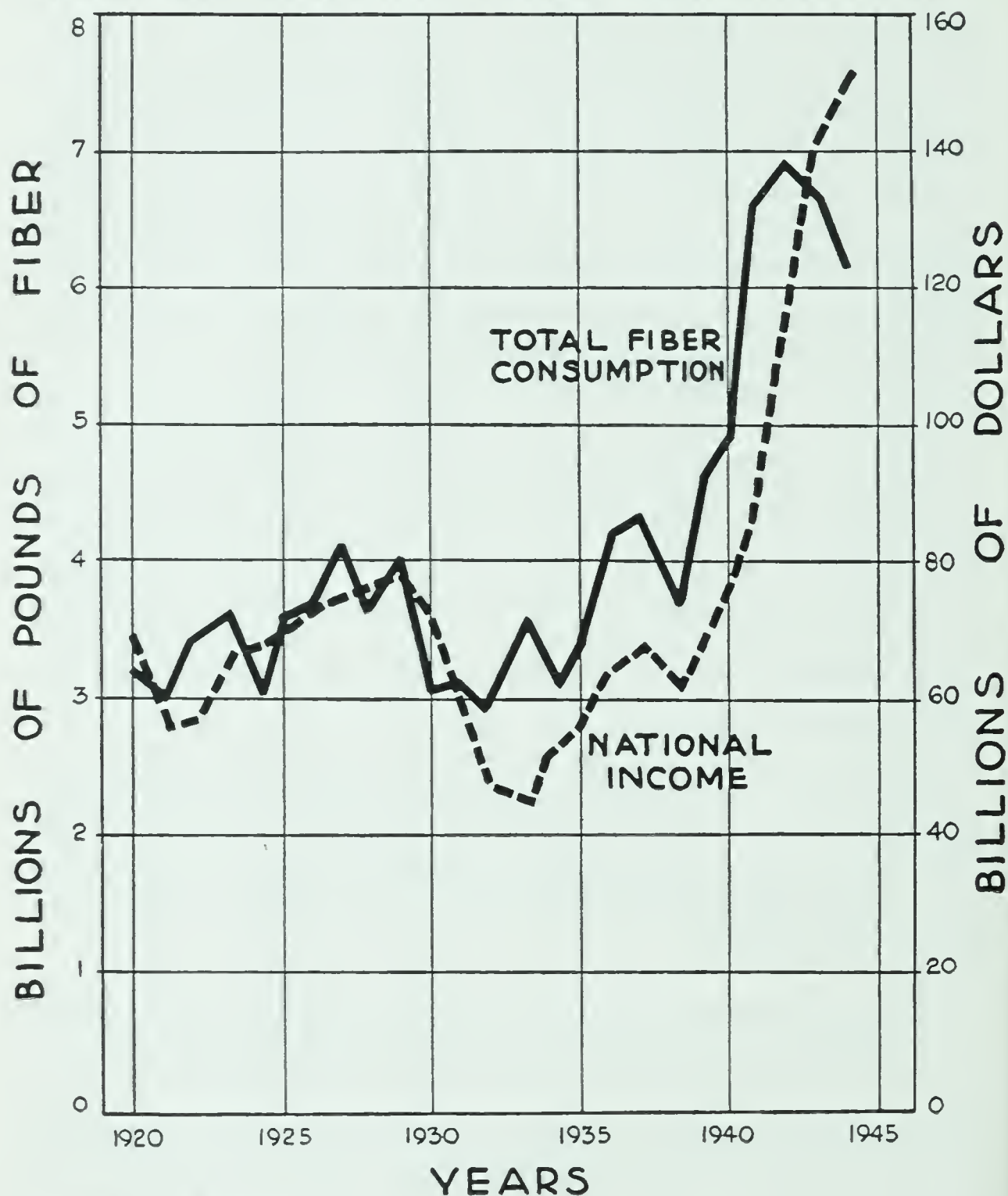
The effect of the mode of living on consumption of such a commodity as textiles expresses itself not only in the amount of any one fabric but also on the type of fabrics consumed. In a society in which there is sharp class consciousness, there is acceptance of certain fabrics being suited only for the use of the gentry; other fabrics, less fine, for the trade; and finally, the coarsest and roughest of all, suited for the farmers and other laborers. This distinction is well phrased in a pamphlet published in 1719: ¹

Our women among the gentry were then clothed with fine English Brocades and Venetians, our common traders' wives and other good country dames with worsted Damasks, flowered Russels and flowered Callimancoes and the meanest of them with plain worsted stuffs.

Sumptuary laws directed toward compulsory observance of class distinction in dress were commonplace both in England and on the continent. Long after these were forgotten as laws, the impelling force of the idea of what was right and proper for the classes affected to some extent textile consumption by these peoples.

Today in our own country there is free textile choice by the consumer, the limit being not what is right and proper for one in a given occupation, but the purchasing power of the individual. As the cost of production has become less through

¹ *The Weavers' True Case*, London, 1719. Cited in *Heritage of Cotton* by M. D. C. Crawford, pp. 101-102. Grosset and Dunlap, New York, 1924.

TRENDS IN NATIONAL INCOME
AND IN TEXTILE FIBER CONSUMPTION

Courtesy Textile Foundation

Comparison of national income and total fiber consumption.

the replacement of hand power with machine power, many fabrics, once limited in market scope, have become widely used. Once fine cotton and wool cloth were available to only a few, as were also brocades and velvets. Now the prices of all

these fabrics are low enough to bring them within the reach of the average person if the choice seems to him more desirable than that of some other good. It is difficult now to place any one type of fabric into a "luxury class" or to predict trends in textile consumption on the basis of income levels or occupation.

Purchasing power. Another determining factor in the consumption of textiles or any other commodity is the purchasing power of the people expressed in the disposable income received, that is, the income payments to individuals, less direct personal taxes. The closeness of this relationship is shown by the graph on page 400, in which the trends of total annual income for the United States expressed in billions of dollars and the total consumption of textile fibers are plotted and superimposed.

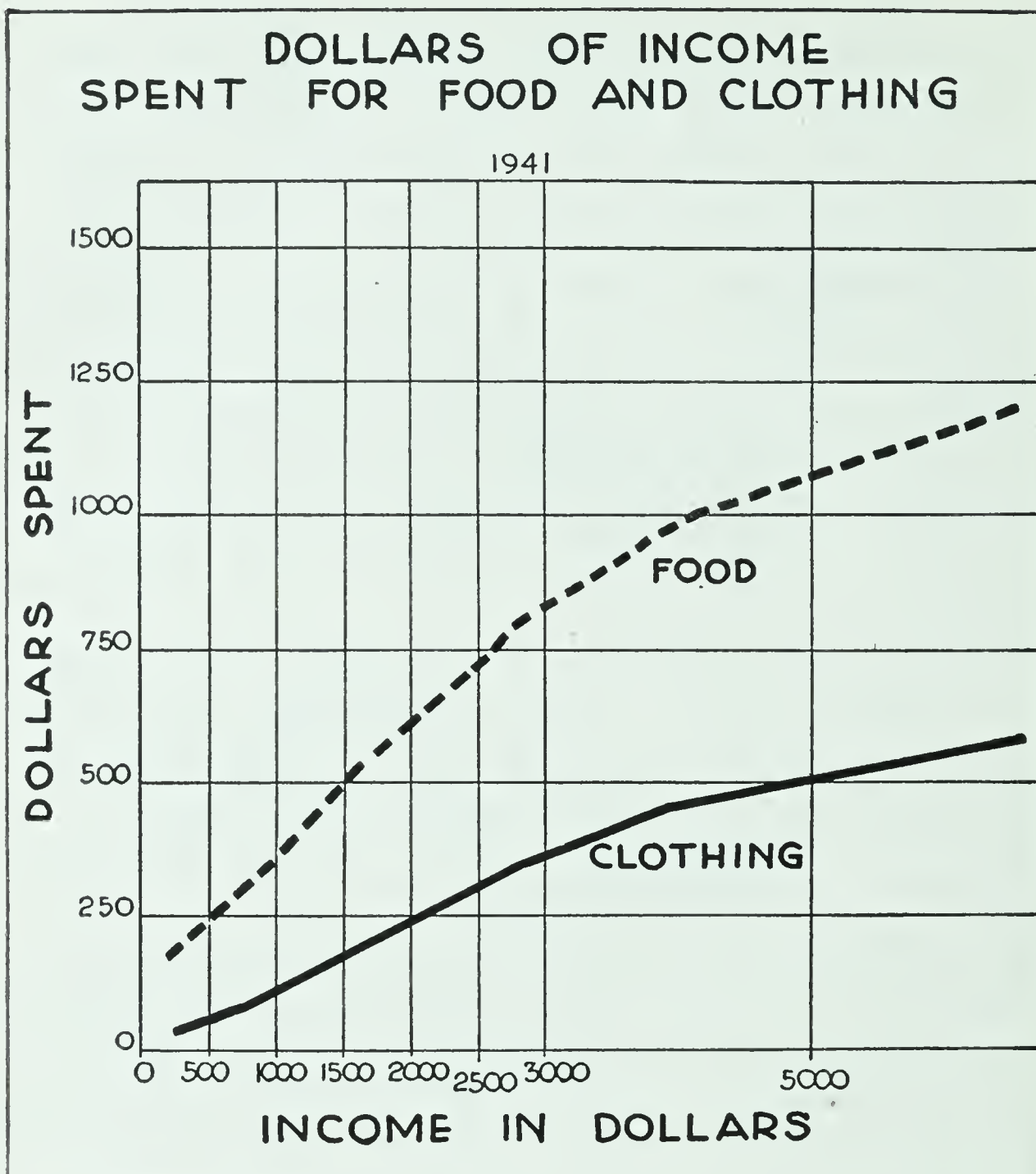
The national income is not the only figure that is important in influencing the consumption of textiles. The distribution of the national income among groups is also important, as upon this rests the purchasing power of the people.

Increases in the income are shown to be accompanied by increases in the dollars spent for clothing and other textile goods. (See the graph on page 402.)

Availability and price. The availability of a fabric affects its consumption. Not only must there be funds for the purchase, but the fabric must be obtainable on the market. Use is fostered by both habit and inertia. There are few cases in which if a given fabric is not easily available a substitute will not be accepted.

In consumer purchasing, price is found to be of great significance. "The price of anything is the amount of money that would be given in exchange for one unit of it."¹ If a yard of muslin sells for forty-five cents, the price of muslin is forty-five cents a yard. Price not only controls production; it also controls the kind and amount of our purchases, thus determining our enjoyment of material things. When prices are low, the possible list of enjoyable things is increased. When

¹ From Fairchild, Furniss, and Buck, *Elementary Economics*, Vol. 1 (1929), p. 24. By permission of The Macmillan Co., publishers.

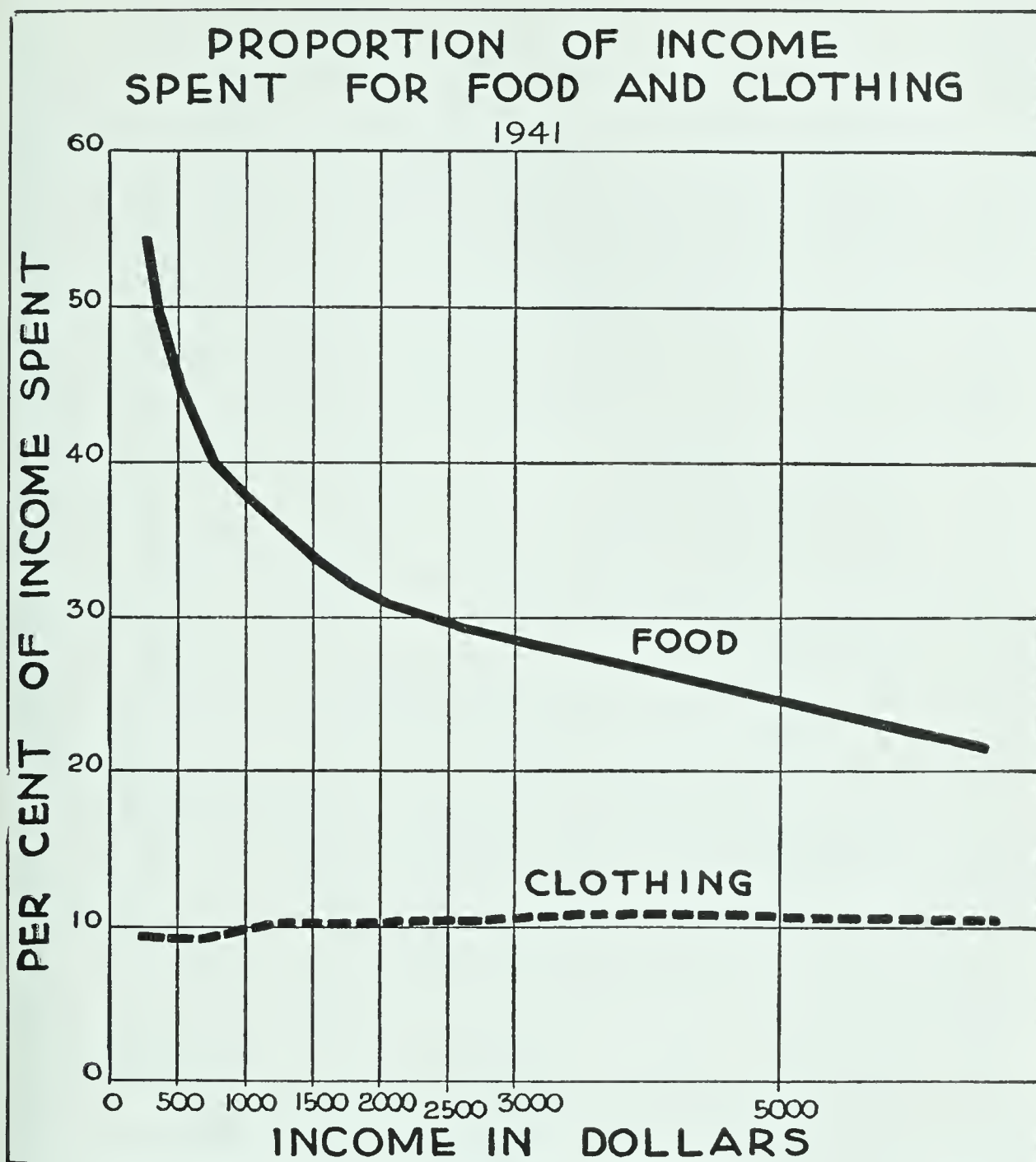


Courtesy Textile Foundation

The dollars of income spent for food and clothing increased greatly in 1941.

prices are high, a curtailment of this list is necessary. Changes in the price of a commodity may change its position from that of a luxury or comfort to that of a necessity.

When there is a choice between two articles, the decision may be based on price. It is frequently stated that price decides what we shall eat, where we shall live, and what we shall

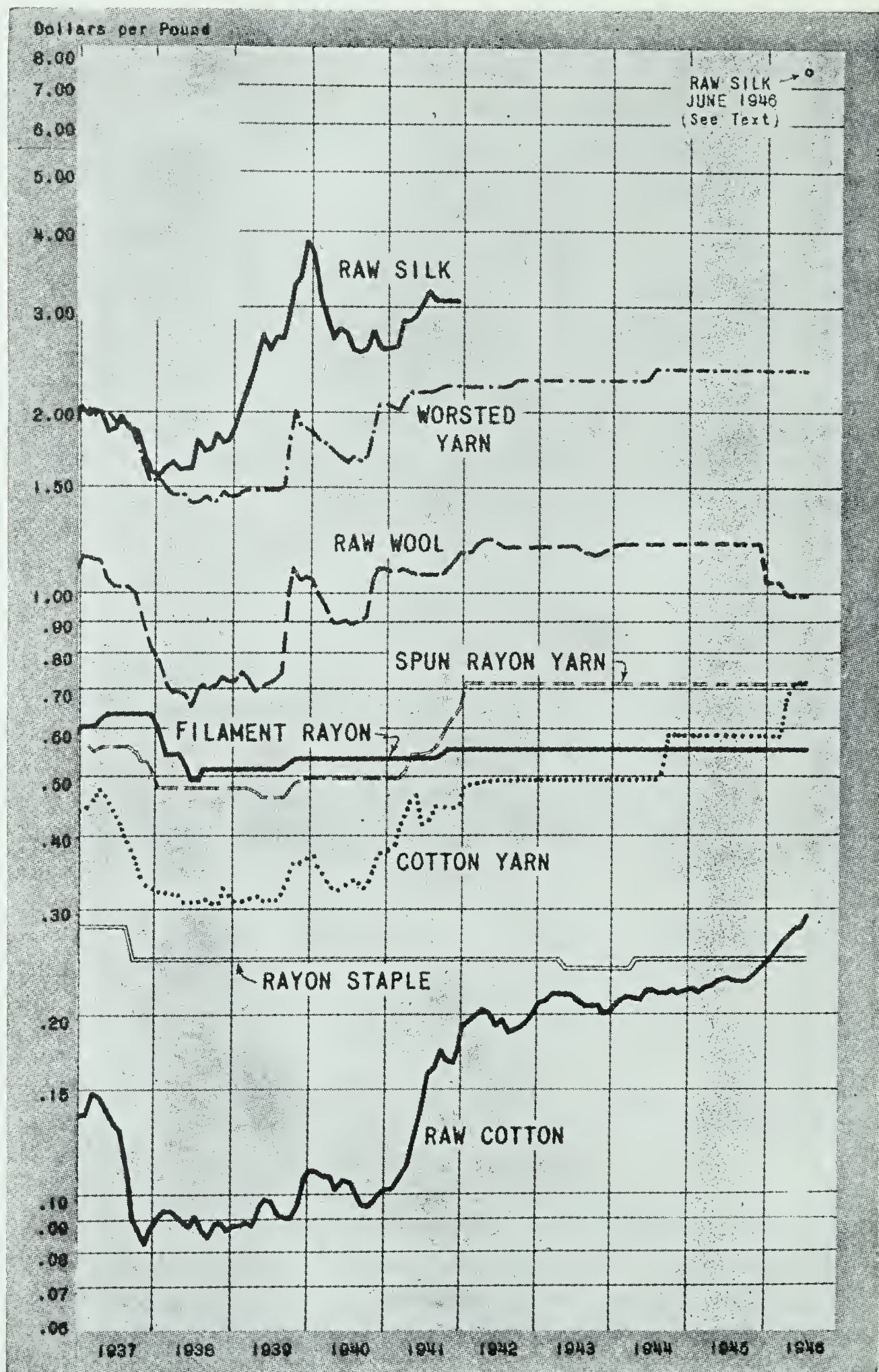


Courtesy Textile Foundation

The proportion of income spent for food and clothing decreased greatly in 1941.

wear. The consumer may exert an influence on prices through his refusal or inability to buy except at a certain level.

In general, when prices are low more people are able to buy, and many people buy in larger quantities if the goods are of relatively constant value to the consumer. Lowering the price of goods for "Clearance Sales" or "Dollar Day Sales" has been found by merchants to be an effective way of disposing



Courtesy "Rayon Organon," August 1946

United States fiber and yarn prices.

of goods that failed "to move" at the original price set. The consumer, in the purchase of food and clothing, generally reacts as the laws of economics would predict, but there is shown an interesting stimulation of sale in certain articles through high prices. Paris hats and gowns, for example, may bring exorbitant prices as far as their textile worth or artistic value is concerned. Some consumers are willing to pay for the satisfaction of the sort of superiority the disproportionate expenditure gives.

Fashion. At the present time, aggressive "high pressure" salesmanship may direct consumption toward given items without markedly increasing the total consumption in the field. Playing upon the wish of people to emulate leaders and observe conventions, the force of trade talk may lead to a purchase of a tweed coat rather than a wool crepe, or a rayon dress rather than one of wool. The push of fashion toward some one textile fiber in preference to the others has contributed largely to the development of finishes that cause other fibers to simulate the one preferred. Thus, consumer demand for wool and silk has led to finishes for fabrics from other fibers which simulate cloth from the preferred fiber so closely as almost to defy identification. "It's the fashion now" is the clamorous call that directs much of the clothing expenditure.

Suggestions for the Laboratory

From library readings determine duties collected on various fabrics in different forms, for example, raw silk, silk cloth, silk costumes; linen yarn, linen cloth, and linen dresses.

The present mode of life has been described as extremely mobile. How does this affect textile consumption? What fabrics in common use in your grandmother's time are not available today? From your reading, present probable reasons for their disappearance from the market.

The rapid development in new fibers, blends, and finishes makes it more important than ever before that the consumer be given information concerning the service qualities of the textiles now on the market as well as the limitations of their new characteristics. This is necessary to prevent their being

improperly used and thus wasted. Merchandise must therefore carry information that will aid the purchaser in making a wise selection for a specific use and also directions for the care of the fabric so that its special characteristics may be maintained.

There is no question as to the fact that consumers are entitled to information concerning the materials they buy, and manufacturers, finishers, converters, garment makers and retail merchants would gladly furnish available information if it could be given in terms of service or performance. The emphasis in labeling of textiles has been on giving facts from which the consumer can form his own judgment. Consumer education as to specifications of quality of raw material, workmanship, and performance that should be selected for a specific need furnishes a valuable background for wise selection. Labels on the merchandise offered for sale are usually the only means of identifying qualities desired.

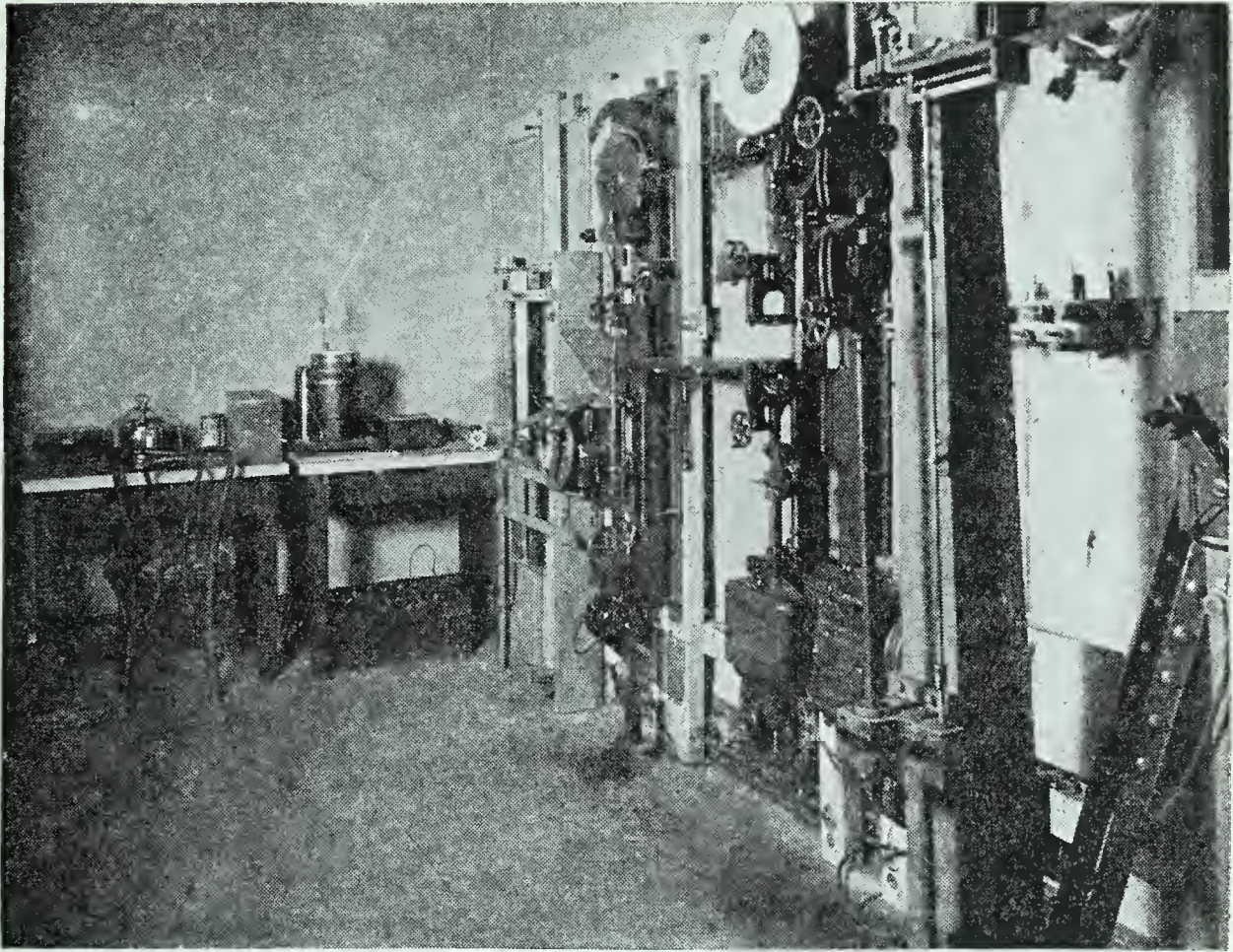
PROBLEM 2. HOW MAY LABELING AID THE CONSUMER IN INTELLIGENT SELECTION OF TEXTILES?

Government testing methods. The purchasing of materials on a basis of quality and suitability is well illustrated in the methods used by the United States government in the purchasing of textiles as well as other articles. The Federal Specifications Board works out specifications covering the minimum requirements for the fabric in question.

The Federal Specifications Board was organized under the bureau of the budget in 1921. It is composed of representatives of each of the purchasing units of the United States government, the chairman of the board being the director of the Bureau of Standards, *ex officio*. Its purpose is to unify government specifications and to bring them into line with the best commercial practice.¹

The specifications for textiles include such items as fiber content, type of construction, color, weight, number of ends

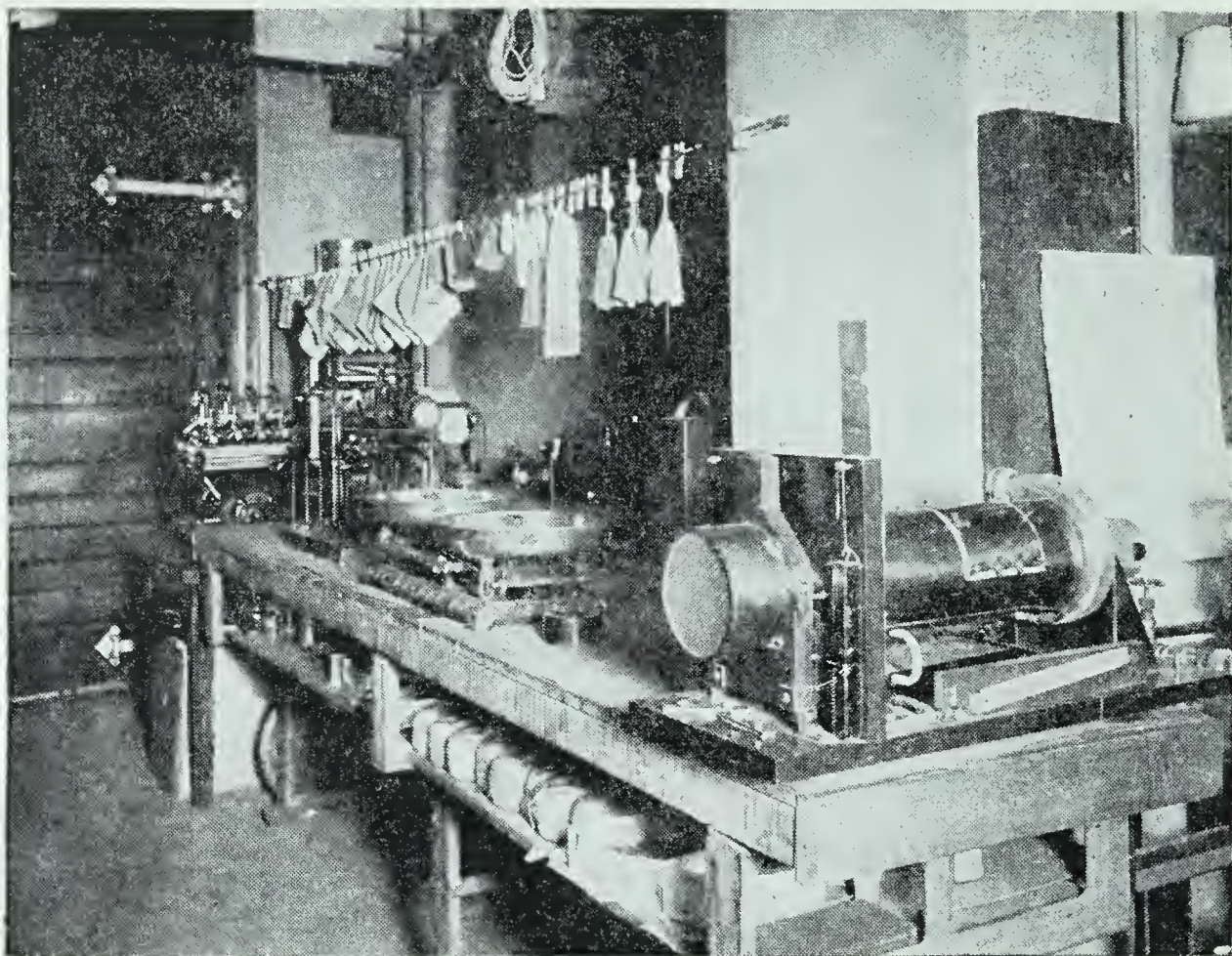
¹ *Encyclopaedia Britannica* (New 14th edition), Vol. 21, p. 305.



Courtesy U. S. Bureau of Standards

View of Bureau of Standards textile-conditioning room. From left to right, flexometer, a portable heat transmission tester in process of development, abrasion tester, two tensile testers, and part of apparatus for measuring tear resistance.

and picks per inch, breaking strength, yarn size, color fastness, and the like. Any manufacturer wishing to make bids for a contract may obtain these specifications. The law requires that the contract be let to the lowest bidder whose material meets the requirements of the specifications. Samples are submitted with the bid and generally the bid is accepted on faith. The materials are later tested at the Bureau of Standards, which was established for the purpose of serving the individual consumer as well as the various departments of the government. Here all tests are made according to definite regulations and rules, in a laboratory (see the pictures on pages 407, 408) where the temperature and humidity are held constant at standard conditions of 65 per cent relative humidity at



Courtesy U. S. Bureau of Standards

View of Bureau of Standards textile-conditioning room. A commercial abrasion tester, yarn reel, balance, and air permeability apparatus.

70° F. If the bidder fails to meet the specifications, material is bought on the open market against his account. By this method it is possible to make purchases on the basis of quality recognized by performance under conditions of standard tests.

Materials, even though produced according to specifications, when subjected to actual use do not always prove satisfactory. In such cases research is carried on, often at the Bureau of Standards, and in time new specifications are formulated.

The consumer ultimately reaps the benefit of any improvement in quality or reduction in costs which results from the cooperation of the Bureau of Standards and the industries.

The cost of textile tests varies slightly under differing conditions, but one representative laboratory doing commercial

testing charges \$3.00 to \$5.00 for breaking-strength tests; \$8.00 to \$10.00 if an elasticity test is included; thread count, \$2.00; thickness measurements, \$1.00; and abrasion tests, including tensile strength and elasticity, \$15.00. The producer must make tests of some kind before he can guarantee his material or place his name on the fabric. As only the better grades are labeled, and as the tests involve cost, the slightly higher price of labeled or guaranteed fabrics is explained.

The Bureau of Human Nutrition and Home Economics in the Department of Agriculture is another agency operated by the government to serve the people of the United States. This bureau includes among its activities the working out of quality standards and research problems on textiles. An important part of this work is the conducting of investigations to determine the needs of the consumer and to assist in obtaining satisfactory materials to meet the consumer's needs.

In 1938 the National Consumer-Retailer Council began to function actively. This organization was formed to coördinate the activities of leading consumer and retailer groups in promoting their mutual interests. . . . Its published objectives are representative of the objectives of the more conservative branch of the Consumer Movement. These are as follows:

- (1) To stimulate interest in the value of adequate standards for consumer goods and to promote the use of such standards.
- (2) To promote use of informative labeling.
- (3) To promote use of uniform terminology in describing consumer goods and services.
- (4) To promote truthful and informative local and national advertising.
- (5) To promote informative salesmanship.
- (6) To develop and promote use of suggested codes of ethics for retailers and consumers.
- (7) To encourage practices which will tend to reduce abuses of such privileges as customer accounts, returned goods, deliveries, comparative pricing, etc.
- (8) To foster coöperation between stores or groups of stores and local consumer groups.

It seems very probable that more precise definitions of fiber

content and statements of quality and service characteristics will ultimately be required.

Broadly speaking, what the consumer wants to know may be summed up as follows:

1. What is the product made of?
2. What will the product do or perform?
3. How should it be cared for—washed, handled, etc.?

Those are reasonable requests which manufacturers and retailers should be willing to help answer.

Quality shown by labels. Everyone is interested in obtaining merchandise of good quality at a fair price. The question of what is best for a particular situation must remain an individual problem. In order to have assurance of quality in manufactured goods it is necessary to have definite specifications of material, of construction, and of workmanship. This statement would be accepted by manufacturer, retailer, and consumer, alike. However, there is no agreement as to who should set up these specifications, what they should contain, or the best means of getting the information to the ultimate consumer of the product. There are at present four distinct theories as to the most effective means of furnishing information to the consumer through the labeling of textiles, namely: informative labeling, the use of brand names, grading, and certification.

To some extent all types of labels are informative, but the nature of the information given distinguishes each type. Truly informative labels must contain factual information. This information may be obtained from laboratory tests made by the retail stores, by the manufacturers, or by independent research laboratories, and should be expressed in common descriptive terms. If the industry would agree not to use common descriptive terms unless these are backed by specific adequate tests, the terms would convey definite meaning and hence serve to inform the consumer. In the use of new fabrics and new finishes consumer education must be not only in new qualities of textiles but also in the limitations of these new qualities.

Informative labeling. Informative labels furnish information concerning the characteristics of the article that affect its appearance and service qualities. The information given may be a description of the article itself, including fiber content and special finishes, or it may be in the form of directions or precautions as to its use and care. Informative labels tend to increase the sale of good quality merchandise as they increase the desirability of honestly labeled products. Satisfaction gained from well chosen articles results in repeat purchases. (See the illustrations on pages 412, 413.)

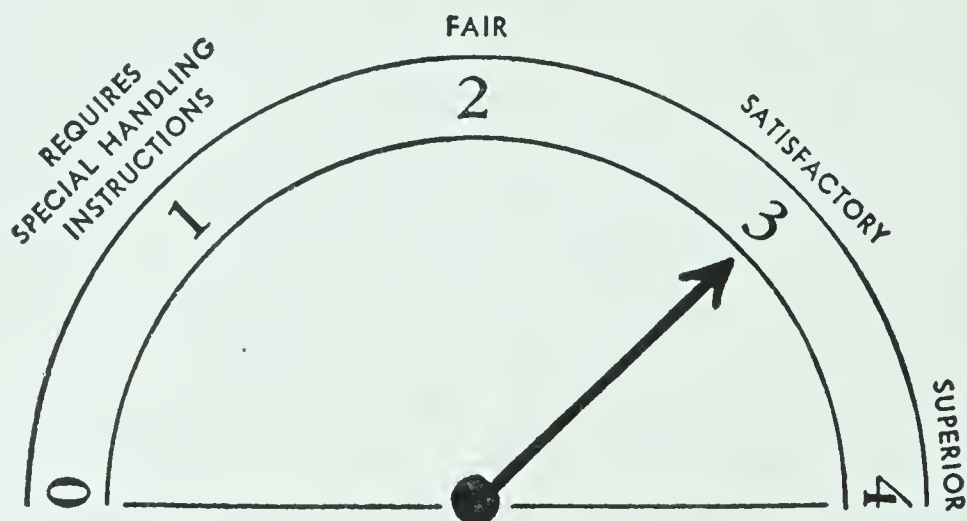
There is some evidence that the use of informative labels increases the cost of distribution. However, there seems to be more evidence that correct use of informative labels reduces the number of returns, makes for satisfied customers with an increase of sales, and thus reduces the cost of distribution.

Much of the failure of informative labeling has been due to the inadequacy of testing methods and apparatus and the correlation of laboratory tests with actual service. The production of fabrics according to stated specifications, that pass certain tests without interpreting these results in terms of service or wearing qualities, leaves the problem only half done. Fabrics are manufactured according to the manufacturer's specifications which give him information as to the material used and the manner in which it is put together. Long experience with cloth enables the manufacturer to vary the specifications in order to produce a fabric with certain specified characteristics.

Manufacturers' specifications of thread count, breaking strength, ounces per square yard, yarn size, twist per inch, percentage sizing, etc. usually give some indication as to the service that can be expected from a certain fabric. However, facts that should be included in consumer specifications are information as to the permanence of its color; size; finish; resistance to creasing, moth, or fire; and the years it would be expected to give this service.

There has been no agreement as to the interpretation of manufacturers' specifications into terms of consumer needs, and much of the information found on labels is of little aid

FASTNESS TO WASHING



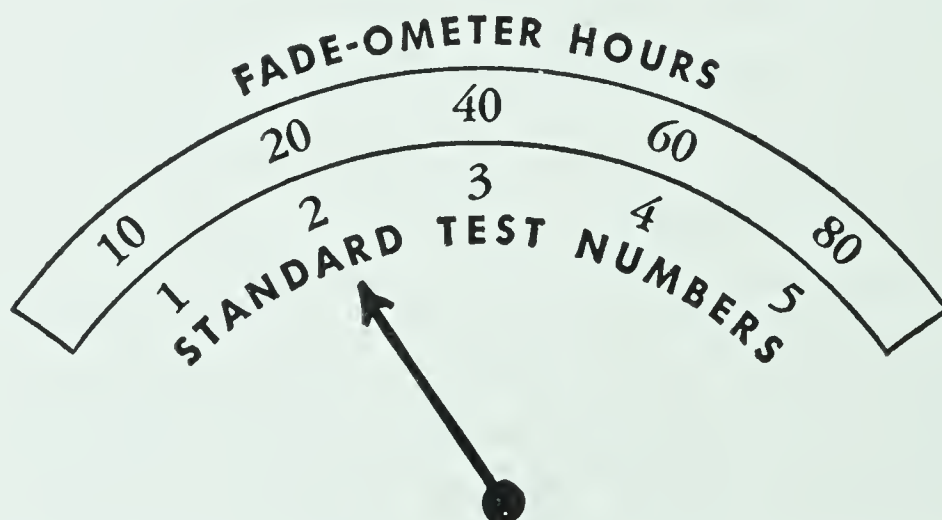
TEST

STANDARD TESTS

- 1 105°F; 0.5% soap, no alkali; for 30 min.
- 2 120°F; 0.5% soap, no alkali; for 30 min.
- 3 160°F; 0.5% soap, 0.2% alkali; for 45 min.
- 4 180°F; 0.5% soap, 0.2% alkali; 0.01% available chlorine; 45 min.

ALL TESTS CARRIED OUT IN STANDARD LAUNDEROMETER

FASTNESS TO LIGHT



The light fastness requirements will obviously vary greatly according to use. For example, drapery fastness requirements may run from 40 to 80 hours (tests 3 to 5), whereas for dress goods 10 to 20 hours (tests 1 or 2) may be entirely satisfactory.

Courtesy Pacific Mills, Inc.

Results of tests for determining serviceability used as basis for labeling.



Courtesy Pacific Mills, Inc.

Such complete information is a great step forward in informative labeling.

in the selection of the best fabric for the least money. Many labels serve as an advertising medium rather than as a consumer aid.

As has been shown in earlier discussions, the quality of the fiber is often of more importance than the kind. New fibers and blends of fibers are made into fabrics of measurable qualities. These are treated with permanent finishes that impart new and varied qualities to the fabric, thus affecting its characteristics and its serviceability.

If the information carried on the label includes a guarantee of performance backed by the name of the manufacturer or finisher, the consumer can buy with assurance of quality. If special precautions are necessary in its care these should be cited. Because of the wide variations of treatment and use that a fabric may be subjected to by different persons, the merchant cannot guarantee the fabrics will hold up under ordinary usage. The term is too vague. A fabric or garment that would give good service to one individual for five years might be ruined by another in one year or less. This fact interferes not only with the guaranteeing of fabrics and garments but also with the informative labeling as to the time or quality of service to be expected.

Brand labeling. The labeling of fabrics with brand names is a well established method and is used widely by the manufacturer as an aid in advertising his products. A study of the advertisements in any magazine or paper will show that this method is used more than any other. A *trade mark* is a word, picture, or symbol used by the company to mark all its products and the *brand* distinguishes between the qualities of goods it offers for sale. The branding of a product indicates that the company producing it has faith in the product and is willing to spend money and effort in informing the public of the special advantages of this particular article.

Established brands, nationally advertised, outsell unbranded articles. This is a decided advantage to the wholesaler and retailer and should indicate a satisfied buying public. Competition in merchandising and advertising tends to compel the manufacturer of branded goods to build up and improve a quality product. The ease with which a branded article can be identified for repurchase if desired is an advantage to the satisfied consumer and to the company putting out high quality merchandise. However, this type of labeling is of no value to the person having no experience with the brand in question. Furthermore, tests have proved that most brands of goods which carry no specific information as to their quality vary widely in quality from time to time. Articles labeled with information concerning manufacturing specifications usually meet the conditions stated.

Grade labeling. Grade labeling by which articles are labeled according to minimum specifications of quality necessitates not only standardization but also some type of organization to check on the merchandise and enforce the rules set up. This type of labeling is considered by some to present a serious threat to free enterprise. Grades are established on a basis of minimum quality or performance and there is little or no incentive to produce merchandise that would exceed this set quality. Another argument against grade labeling is that many articles would almost meet the requirements of Grade A and be far above those of Grade B but would have to be labeled Grade B. As the subdivision of grades would be impractical the manufacturer would doubtless reduce the quality of his product to the minimum requirements of the grade. Unless some government organization establishes the grades and publishes detailed descriptions for each with rules for their enforcement, there would be no assurance that corresponding grades of different manufacturers would be of the same quality.

Grade labeling is seldom used in the merchandising of textiles. However, the specifications set up by OPA with regard to the manufacture of sheeting, although listed as types, could be considered as illustrative of grade labeling. The qualities as specified for their best type were below those of fabrics already on the market. The rulings permit as much as four per cent sizing in the highest quality and, prior to their use, fabrics had been on the market labeled as containing less than one per cent sizing. No mention was made of shrinkage in the OPA specifications and this is important consumer information.

Certification. Certification of fabrics by certain independent textile testing laboratories is considered by some to be a consumer service approaching the government method of purchasing. By this method of labeling, laboratories, in no way connected with the manufacturer or finisher, set up specifications which according to their experience will result in fabrics satisfactory for consumer use. No information is given on the label except the statement that the fabric has been tested and has met the specifications. Laboratories furnishing



Courtesy United States Testing Co., Inc.

Basic seal and label of certification.

this service to manufacturers or finishers test the fabrics submitted for test and if they meet with the specifications set up the company is permitted to use the label of this testing laboratory. This service includes a periodic check on material appearing on the market to prove that the fabrics still come within the limits of the specification.

Copies of the specifications can be obtained by writing

to the testing laboratory but are not included on the label because of the space required for complete information and because they are in manufacturer rather than consumer terms.

The value of this type of labeling is determined entirely by the reliability of the testing laboratory as it alone is responsible for the qualities indicated by the label. (See page 416.)

Testing laboratories maintained by the manufacturers themselves enable them to determine the quality of the fabrics they produce and thereby label their goods as guaranteed to give certain types of performance or as "Tested" or "Certified." Such labels are of no more value to the consumer than the brand name. (See the illustration on page 417.)

The wide use of special or service finishes for many types of fabrics has increased the use of informative and brand labeling. Some companies guarantee the permanence of the finish and state the service it will give; others simply explain the qualities produced by the finish and give directions for the correct handling of the fabrics.

PROBLEM 3. HOW DO SPECIAL FINISHES ENHANCE THE VALUE OF FABRICS?

Great demands were placed on the textile industry for enormous quantities of fabrics with special characteristics for

specific needs during the recent war. This stimulated the development of new permanent finishes which gave to fabrics characteristics they had never possessed and also increased the use of other finishes known but seldom used. Because these fabrics were needed at once, short cuts in methods were worked out; the shortage of labor necessitated improvements in machinery already in use and the development of machine methods for processes which had previously been done by hand.

To serve under war conditions wool garments had to be permanently moth and shrinkproof; colors had to be fast to sun, weather, and washing; equipment had to be light in weight and durable; and fabrics must be provided that shed water and still were comfortable. There was special need for fabrics that resisted all types of pests as well as mildew and rot. Durable insect netting and hammocks, crease-resistant cloth, and fabrics that were warm yet light were among the demands which confronted the textile industry.

The war production of standard fabrics of many previously unknown and often considered impossible finishes is one of the marvels of this century. These finishes are now available for consumer goods, making possible a variety of fabrics never known in the history of textiles. Information concerning the effectiveness and permanence of fabric finishes is a necessary basis for wise selection by consumers.

We have been told that the fabrics of the future will be made-to-order according to measurements of consumers' specific needs. We will buy not certain fibers or blends, not fabrics in which the fiber content, yarns per inch, and ounces per square yard are known, but we will purchase fabrics with de-



Another type of label indicating the manufacturer's certification.

sired qualities such as warmth or coolness; permanence of size, color, and texture; and resistance to wear, creasing, mildew, fire, and moth. These qualities will be obtained by means of service or special finishes. The term special as used here will cover those finishes that are designed for a special purpose. Some finishes of particular interest to the consumer are those giving qualities of softness or stiffness, color fastness, flame or fireproofing; resistance to creasing, shrinking, moth, and mildew; moisture absorption or moisture resistance, and antiseptic qualities.

Several types of materials are used in applying special finishes to fabrics. Rubber and synthetic rubber, plasticizers, vegetable and mineral oils of different types and forms have been used for many years in the finishing of textiles, especially cotton. Developments in polymer chemistry are furnishing a wide variety of resins which when used in the finishing of textiles increases their durability and enhances their value by imparting to them certain properties which they do not normally possess. Plasticizers, high boiling organic liquids, are used mainly in conjunction with resins to make them softer and more flexible.

Polythene, the simplest of the vinyl polymers, is inert chemically, being practically insoluble in all cold organic solvents. This polymer, when melted in contact with fabrics, forms a laminated or coated effect. This is used in producing a permanent anti-crease finish, especially on rayon. Polyvinyl chloride, another vinyl polymer resin, when combined with a suitable plasticizer imparts a resistance towards attack by acids, alkalies, and oxidizing agents, which has proved a suitable finish for protective clothing. Polyvinyl acetate is not only an important resin for use in finishing fabrics but is an important starting point for the preparation of polyvinyl alcohol, polyvinyl butyrol formal, and acetate. These compounds possess a wide variety of properties such as pliability and toughness. Differences in types exist, such as water soluble products, aqueous dispersions, and organic solvent solutions.

One of the best known condensation polymers is an inter-

mediate condensation product of formaldehyde and urea. This is used by one company in the production of a permanent anti-crease finish for viscose spun rayon. The components are applied to the fabric and the resin is built up by a heat process. A similar process is used in the production of a permanent anti-shrink finish. In these processes the thermo hardening resin is formed inside of, as well as on the outside of, the fibers.

Fabrics that have been finished with a *service* or *special* finish, because they have been given desirable properties they do not naturally possess and undesirable properties have been destroyed, must carry a label containing this information. The name of the finish is usually the trade mark of the finisher or manufacturer and the label is more or less informative, often a guarantee of performance.

Crisp cottons that can be laundered without starching; cottons, linens, and rayons that resist wrinkling or from which the wrinkles "hang out"; wash fabrics even of wool that neither shrink nor stretch; water-repellent fabrics that are comfortable and yet keep you dry; and wools that moth will not eat are some of the fabrics made possible with these new permanent finishes. The finishes are discussed in alphabetical order and the trade names of some of the finishes with their effect on the fabric are given in alphabetical order in the table on pages 428, 429.

Absorbent finishes. The purpose of this type of finish is more rapid drying action. Although not in common use an absorbent finish is sometimes given to towels to cause them to absorb more moisture and more rapidly than they otherwise would. Materials treated with an absorbent finish not only absorb but also evaporate more readily than untreated fabrics. New materials given this type of treatment absorb perspiration as readily as fabrics that have been laundered many times. This finish is applied to cotton and rayon. *Sorbtex* and *Telozorbant* are finishes of this type.

Antiseptic finishes. Antiseptic finishes became of vital importance during the recent war. One type reduces the tendency for growth of bacteria or germs that might prove a health

hazard. This type also prevents or retards the absorption of perspiration odors by garments. Another type prevents or retards rotting or deterioration caused by mildew or molds. *Sanitized* and *Sani-Age* are finishes of the first type which claim to inhibit the absorption of perspiration odors. These finishes are applied to all fibers.

Crease-resistant. Wool and silk are highly resistant to creasing, but cotton, linen, and rayon are much inferior in this respect. Not until certain types of synthetic resins were discovered had this difference been eliminated. A process long in use in England has recently been widely used in this country. Synthetic resins in water solution are applied to the yarns or the fabric. It is then heated to a high temperature to polymerize the resin. This treatment produces an insoluble resin both on and in the fibers. The fabric is not only made crease-resistant but may acquire one or many other desirable qualities such as color fastness, shrink resistance, resistance to spotting, increased strength and wearability, better appearance, and better hand.

Urea-formaldehyde resin has been used for crease-resistant finishing for many years. Recently, melamine-formaldehyde resins have been applied for this purpose and indications are that the treatment will surpass the older type in importance. It is possible by means of melamine resins to produce on cotton and linen one permanent finish which will resist creasing, moisture absorption, shrinkage, and mildew. *Vitalized* and *Tebilized* finishes are examples of crease-resistant finishes. These are applied to cotton, linen, and rayon.

Flameproof or noninflammable finishes. Flameproof or noninflammable finishes have been used to some extent for many years but often with doubtful effect. All fabrics made from cellulose material will burn, but the rate of burning varies with the type of material and the finish. Those that burn rapidly are termed inflammable. The use of the term noninflammable does not indicate that the material is fireproof. The fabric may char and glow but will not carry a flame. One type of fireproofing process covers the fabric with soluble salts and another type deposits insoluble compounds

either on or in the fabric. Soluble salts do not provide a permanent finish and hence this method has been replaced by one using a deposit of insoluble compounds. Stannic oxide used for this purpose has been precipitated by many methods. This compound does not prevent the burning of a fabric after it has been exposed to rain nor does it prevent the destruction of the fabric by charring. Exposure to sunshine also causes deterioration of the fabric.

It was found that certain highly chlorinated organic substances—such as vinyl chloride resins, chlorinated rubber, and chlorinated paraffin wax—prevent afterglow. This treatment also renders the fabric somewhat water-repellent. They do not, however, prevent deterioration of the fabric when exposed to sunlight. Colored metallic oxides lessen this effect.

It has been found that all of the materials needed for successful flameproofing of a fabric can be applied at one time with the addition of a volatile organic solvent. This greatly simplifies the process and reduces the time necessary for its accomplishment.

There have been several attempts at legislation to prevent accidents caused by inflammable fabrics. The lack of accepted standard test methods and definitions has interfered with successful passage and enforcement of such bills. A subcommittee of the American Association of Textile chemists and colorists in evaluating the flammability of textiles arrived at the following conclusions:

1. Wool, silk, nylon, vinyon, and velon fabrics offer no flammability hazard.
2. Cotton is just as flammable as regenerated type rayon under identical construction and testing conditions.
3. With cotton having a normal moisture regain of 6½% as compared to regenerated type rayon with 11% it is reasonable to conclude that cotton will come to the critical point much more rapidly than rayon.
4. Certain coated fabrics, although generally slow to ignite, burn with a violent flame which is difficult to extinguish, and therefore offer a very definite fire hazard.
5. If the samples of any one fabric are all in identical con-

dition as to moisture content and physical condition of the face being tested, very close correlation of results can be obtained.

Mildew, mold, and rotproofing. Mold and mildew discoloration and damage of textiles are the result of the growth of the low forms of living matter classified under the headings of bacteria and fungi. These abound in great quantities in the soil and break down organic waste matter into a form easily assimilated by plants. It is this property of organisms of breaking down organic matter that causes rot damage in textiles. All cellulose and protein fibers are more or less susceptible to rot, mold, and mildew but the cellulose fibers, cotton, linen, and the rayons are readily attacked by these organisms.

Bacteria do not attack clean fibers unless they are very moist; therefore most of the microbiological damage of textiles is due to a fungus of some type. Fungi exist in many varieties; those resulting in mildew in textiles are very small in size, and are commonly called molds.

Mildew growth does not develop except where high humidity, warmth, and starch or sizing are present. The fungus spores are always present in the air and are easily deposited on textiles. Mildewproofing agents or fungicides commonly used on textiles are not proof against weathering but protect the cloth during processing, storing, or shipping. Rotproofing must protect not only from microorganisms but also from the effect of sunlight, air, and water. This ideal has not been fully realized; however, certain treatments do prolong the life of the fabric well beyond that of an untreated one.

A coating of some impervious substance such as bitumen or rubber furnishes a successful waterproofing treatment. Most of the rotproofing treatments for cellulose textiles make use of substantially water-insoluble chromium and copper compounds.

Mineral khaki processes, which have been widely used, are well known chromiumproofing treatments. Cotton goods are treated with water soluble salts of iron and chromium which are fixed by after treatment with an alkali in the form of hydroxides or hydrated oxides or with potassium chromate. The

simplest of the copper rotproofing processes is the copper carbonate method.

Although the chromium and copper carbonate processes afford excellent protection against microbiological attack, they afford little resistance to weathering.

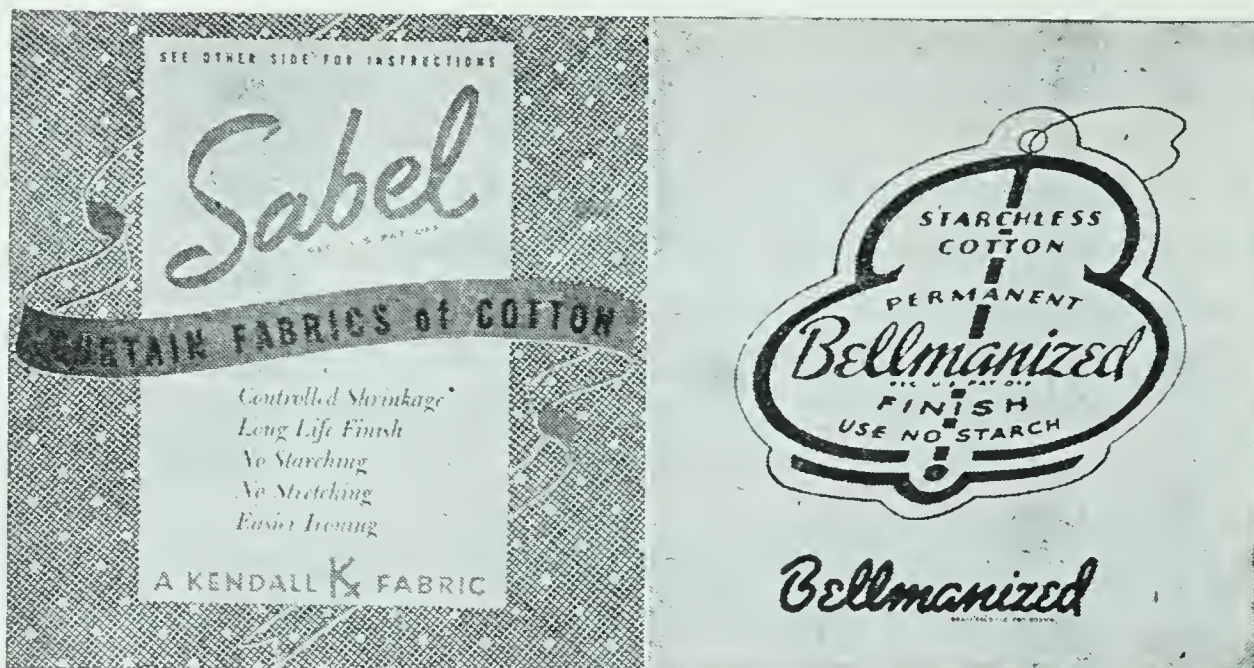
Certain thermo-hardening formaldehyde resins, when used as finishing agents on textiles, enhance the resistance of these fabrics to microbiological attack and weathering. Future developments along this line may provide the rotproofing treatment desired.

Moth resistant or mothproof finishes. Moth resistant or mothproof finishes are of great economic value as millions of dollars' worth of damage result each year from destruction of wool fabrics by moths and beetles. This subject is discussed in Section III, Unit II, page 563. *Eulan*, which is really a dye, is guaranteed to render the fabric mothproof. This finish has been used to a limited extent for many years but has not been available in quantity. *Nevamoth* guarantees the fabric against moth damage for five years. *Larvex* is a third type of moth resistant finish. These finishes are applied to wools and Aralac. However, Aralac is generally made mothproof during manufacture.

Starchless finishes. Starchless finishes give to the fabric a permanent finish which resists wilting and soil. Crispness and transparency, softness or a linen-like appearance may be attained with this finish. Fabrics given a starchless finish to make them permanently crisp will not soil easily nor lint. This finish is used sometimes to give a special rippled finish known as plisse or seersucker. The white pigment stripe or design is produced on cotton by a strong chemical and requires special apparatus for its application. This finish is applied to cotton. *Sabel*, *Apponized*, and *Bellmanized* are starchless finishes. (See the illustration on page 424.)

Shrink resistant. Controlled shrinkage that would permit the finisher to guarantee not more than one per cent residual shrinkage should be a standard finish for all fabrics.

The *Rigmel* finish and the *Permashrunk* finish are two types that carry guarantees of little or no shrinkage.



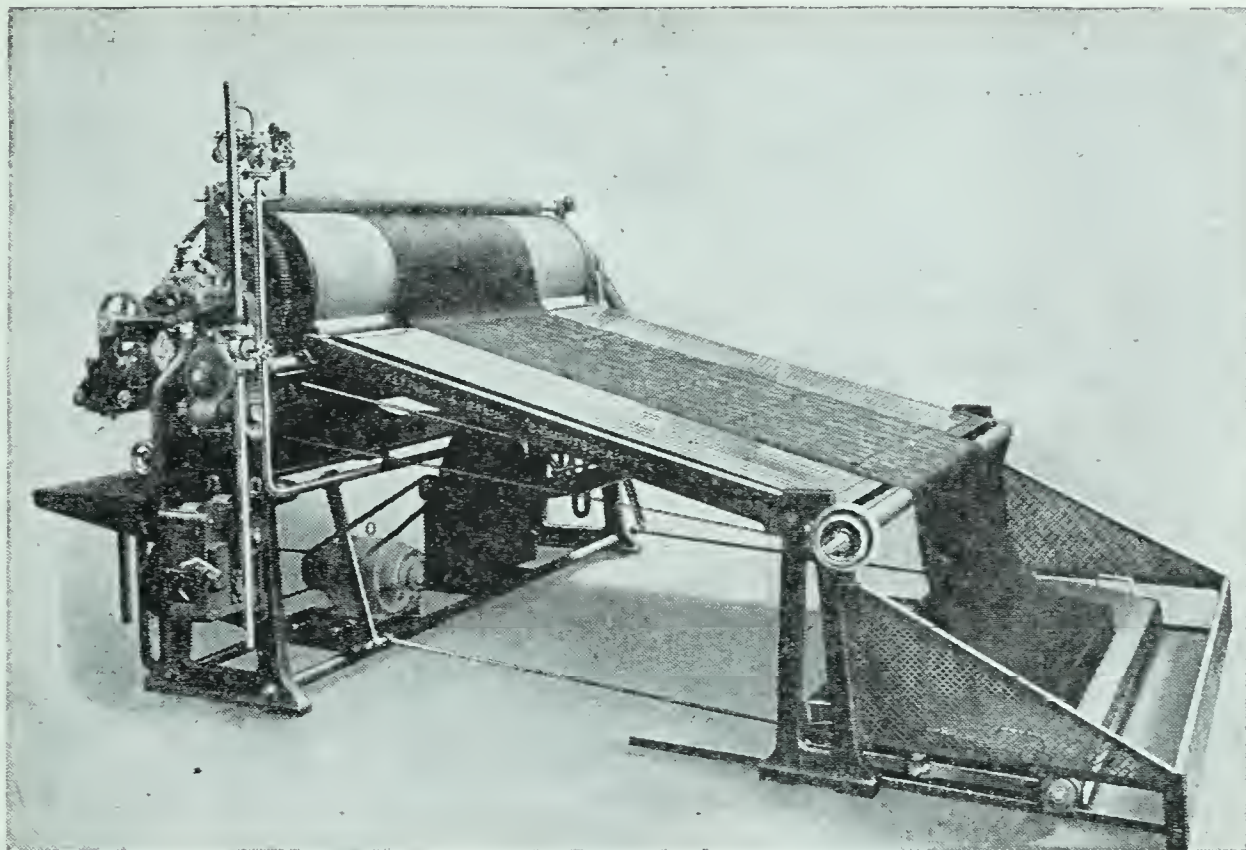
A starchless finish may be used alone or with other finishes.

Crepe fabrics are successfully made nonshrinkable by the use of a small amount of synthetic resin. Crepe fabrics so treated can be laundered with safety.

Various types of labels concerning shrinkage are placed on fabrics and garments for sale. However, unless these labels carry a guarantee of the maximum amount of shrinkage that will occur, their value to the consumer is negligible.

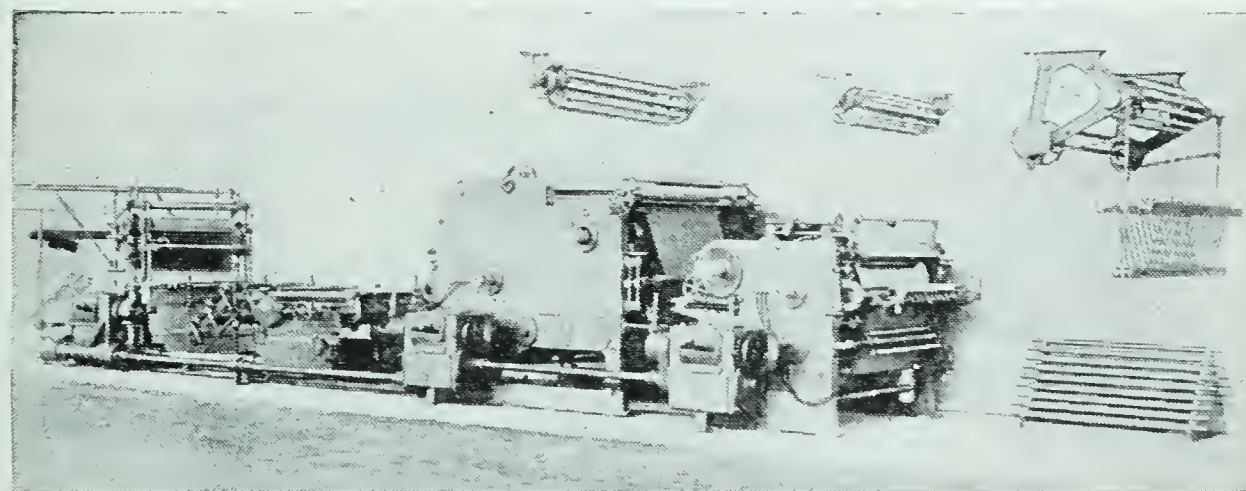
One type of cloth-shrinking machine in which maximum shrinkage is claimed is shown in the picture on page 425. In this machine a feeding roller is so arranged that the cloth is fed onto the steaming roller in ripples. From here the material is forced or pushed onto the hot plate where the shrinkage really takes place. This highly polished plate is so placed that the cloth slides down the surface without tension. The placement of a roller at the lower end of the plate prevents too fast movement of the cloth, and the rising movement of the cloth prevents it from lying flat; thus elimination of tension is insured. It is claimed that this type of machine provides almost complete shrinkage.

Each length of fabric will shrink a definite number of inches or fractions of inches, depending upon the amount of tension exerted during the various finishing processes through which it has passed. One method of controlling the shrinking



Courtesy Kettling and Braun

Machine illustrating a method of controlling the shrinking of cloth.



Courtesy Cluett, Peabody and Co., Inc.

Complete Sanforizing range.

of the fabric includes testing each piece of cloth to determine the amount it will shrink and then feeding it, in a moistened condition, through apparatus in such a manner that the length will be reduced the determined amount. This process is termed Sanforizing. Fabrics treated in this manner may



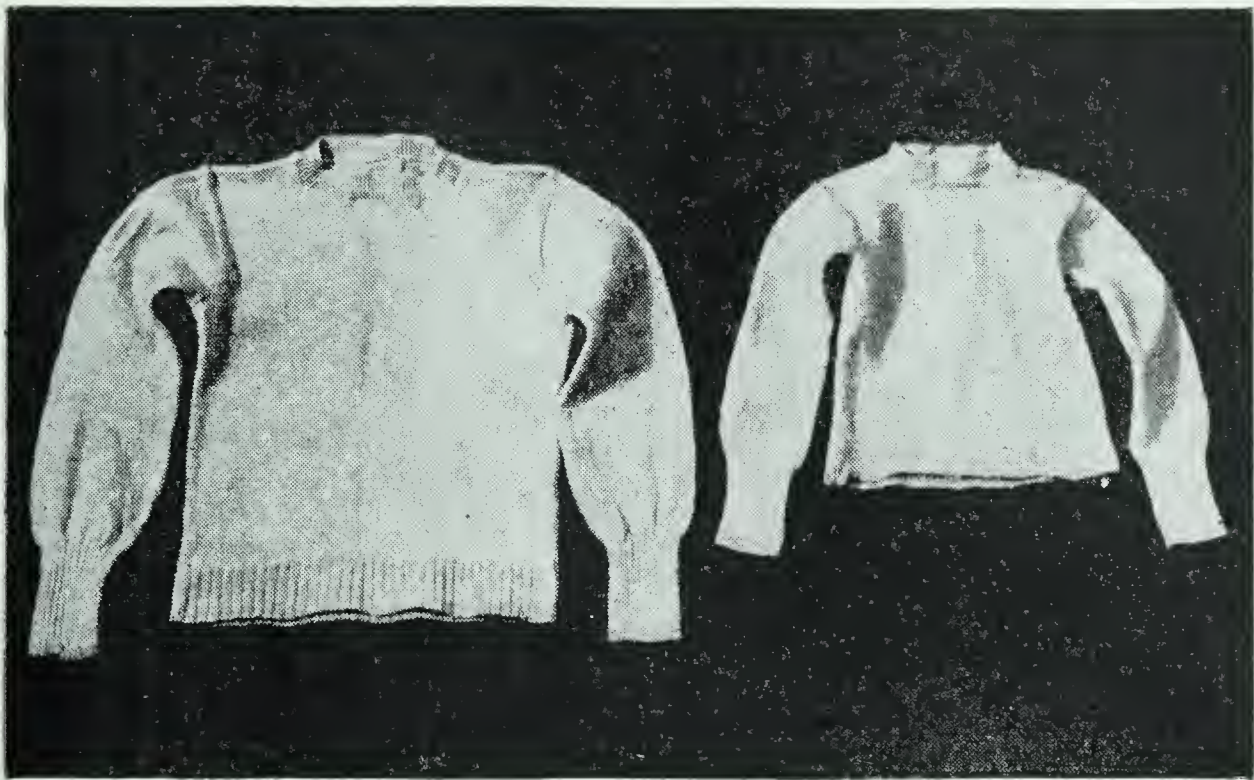
Courtesy Cluett, Peabody and Co., Inc.

Labels giving positive guarantee against excessive shrinkage:

carry a label guaranteeing a shrinkage of not more than one per cent. (See the illustration above.)

Waterproof and water-repellent finishes. Some special finishes which give to textiles properties they did not normally possess, such as waterproofness, have been known for many years. The materials and methods first used in many cases, while enhancing one quality of a fabric, reduced or entirely destroyed other desirable qualities. The first treatments given to fabrics to prevent the passage of water through them closed the pores of the cloth, making them uncomfortable for wearing apparel and changing the appearance of the cloth. This type of finish is still in use today and is designated by the term *waterproof finish*.

Water-repellent finishes cause the fabric to resist the pas-



Courtesy American Cyanid Co.

Two sweaters differing only in that the one on the left was treated with Lanaset, a treatment which controls shrinkage. Both were given the same laundering test.

sage of water through them and at the same time permit the free passage of air. The fabric is not changed in appearance or texture and its durability is not impaired. Water-repellent finishes are classified as "Renewable," those that must be renewed after each cleaning because both laundering and dry-cleaning remove them, and "Durable," those that will resist at least three dry-cleanings and are affected but little by laundering. Renewable water-repellent finishes will be identified by a gold tag attached to a sleeve button, and the durable type will be identified by a blue tag, according to an agreement made by 22 converters of cotton goods.

Renewable water-repellent finishes consist of a wax or gum used in the form of an emulsion. *Aridex*, *Aqua-Sec*, and *Impregnole* are examples of renewable water-repellent finishes. (See the illustration on page 430.)

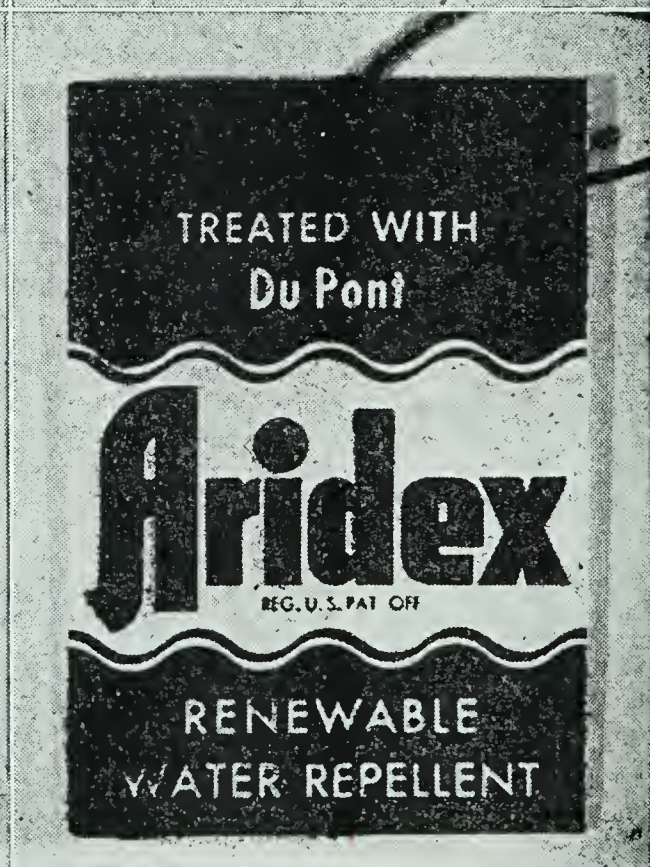
Durable water-repellent finishes are usually complex organic chemicals which penetrate into the individual fibers. *Zelan* and *Cravenette* are examples of this type of water-repel-

CHARACTERISTICS OF SPECIAL TEXTILE FINISHES

SUMMARY OF SPECIAL TEXTILE FINISHES	Absorbent	Crease- resistant	Crisp, non-wilting	Flame resistant	Mildew resistant	Moth resistant	Shrinkage resistant	Stretch resistant	Waterproof	Water- repellent
Absorbenized	X									
Apponized			X							
Aqua-Sec					X					X
Aridex			X		X					X
Ban-Flame				X						
Beautanol					X				X	
Bellmanized			X							
Cravenette					X					X
Definized							X			
Drax				X	X					X
Eulan						X				
Ever-Glaze			X				X			
Fiberset							X	X		
Impregnole										X
Koroseal					X				X	
Larvex						X				

CHARACTERISTICS OF SPECIAL TEXTILE FINISHES

[illegible]



A group of labels indicating different types of water-repellent finishes.

lent finish. (See page 430.) *Drax* is an example of a compound that can be used in the home to give fabrics a water-repellent finish.

Finishes that render a fabric moisture- or water-repellent also render the fabric resistant to soil and stains. For this reason fabrics which have a water-repellent finish are excellent for use as house dresses, play suits, and children's clothing. If finished with the durable type, these garments may be thrown into the machine and handled with the rest of the family wash without danger of removing the finish. Stains are easily and quickly removed without special treatment because they are on the surface of the cloth and have not penetrated the fibers.

Suggestion for the Laboratory

Select from magazines and newspapers, advertisements that illustrate the various types of labeling. How much of the advertising is in the form of emotional appeal and gives no information concerning the product?

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Unit Two

HOW TO SELECT FABRICS FOR CLOTHING AND HOUSEHOLD USE

IN THE selection of a fabric the consumer desires that the article furnish him with satisfaction, both immediate and remote. The three qualities demanded of fabrics are attractiveness, suitability, and serviceability. In other words, the article should meet acceptably the need for which it is purchased. This requires an intelligent analysis of the situation by the consumer, covering the type of fabric—as velvet or sheeting; the durability of the fabric—as determined by such service qualities as washability and color fastness, or cleanability and crease resistance. On the basis of such an analysis the consumer is faced with the necessity of a wide knowledge of textiles if he is to buy intelligently.

The consumer often evades his responsibility by allowing the saleswoman to make the selection. The saleswoman, like the consumer, generally lacks accurate information on which to base her choice and she may not understand the factors governing the specific situation. Only when situations are resolved into their component parts and a study made of these, will definite information be available concerning the requirements necessary to meet specific needs. Specifications for fabrics covering these requirements must be formulated, cloth placed on the market must be labeled according to quality, and ratings must be affixed to the fabrics, before guesswork can be taken out of shopping.

PROBLEM 1. WHAT SHOULD BE THE BASIS FOR THE CHOICE OF CLOTHING FABRICS?

The selection of clothing fabrics is one of the most difficult problems of the consumer. This is true with regard to clothing for men and boys as well as that for women and children. The problem is made difficult because of the multiplicity of clothing needs as well as the volume and variation of materials available from which to supply these needs. There is a great contrast between the few garments of staple fabrics which constituted the clothing of our grandmothers and the wardrobe of any well-dressed woman today.

The clothing selected by a person living only fifty years ago would include garments made from fabrics of standard construction, as muslin, serge, flannel, and taffeta. Selection involved no question as to whether knitted or woven materials would serve best. It was a matter of knowing whether one wished wool, silk, cotton, or linen and of buying accordingly from the available staple fabrics.

Today the natural fibers are combined with each other or with synthetic fibers quite as often as they are used alone. The matter of choice is further complicated by the fact that staple fibers are spun on the cotton, linen, wool, or silk system. These yarns, in combination or alone, are knitted or woven into many new and novel constructions. If the fabric is given one or many special finishes, there are several new properties introduced, all of which combine to make selection more difficult. All of this points to the need for careful and intelligent consideration of clothing needs and fabric choices.

As we have already learned, fabrics made from any fiber vary over a wide range in thickness, texture, and weight. We have also found that the properties of cloth are affected by the fiber, the yarn, the method of construction, and the finish. The knowledge thus gained should guide us in judging the wear or service obtainable from certain types of material. We should not expect a satin-weave fabric with long floats of loosely twisted yarn to stand up under hard wear, or a heav-

ily weighted silk to serve as a wash fabric, or sheer material to be practical for children's play clothes.

Price. In the purchase of any article the amount of money to be expended is one of the governing factors in the selection. If we can spend but a few cents a yard for cloth we need not waste time at the silk or wool counters. In proportion as the amount of money to be expended is increased, the list of available material is lengthened and selection at a given cost becomes more complex.

Have you ever listed under each item of clothing the fabrics that are often used for that purpose? A study of the table on page 436 will indicate the possibilities that perplex the consumer in her choice.

Fabrics used for underwear should meet certain definite requirements such as softness of texture, ease of laundering, high porosity, fastness of color, and durability. Other necessary qualities may come to your mind. What determines such properties in cloth? What relation do these bear to its cost?

The width of the cloth is an important factor in the price of any article made from it. Often a wide fabric is more economical than a narrow one that costs less per yard. The variation in the amount of material required for a certain use because of difference in the width of the cloth is shown by the following figures:

AMOUNT REQUIRED	WIDTH
2 yds.....	32 in.
1 $\frac{7}{8}$ yds.....	36 in.
1 $\frac{5}{8}$ yds.....	40 in.

These data are typical of the information to be found on patterns. Dress goods are seldom found in 36-inch material because it is difficult to cut a garment from such narrow widths. Fifty-four-inch material usually cuts to the best advantage for suits and coats. It requires time and effort to determine the most economical width and the yardage required, but this knowledge often permits the purchase of a better fabric than at first seemed possible.

TYPICAL FABRICS FOR COMMON GARMENTS

UNDERWEAR	DRESSES FOR SCHOOL OR BUSINESS WEAR	COATS	CHILDREN'S WEAR
<i>Wool</i>			
	Shepherd's check Novelty weaves Serge Flannel Tweeds Cashmere Crepe Gabardine Challis Jersey	Flannel Tweed Novelty weaves	Light-weight flannel Crepe Batiste
<i>Cotton</i>			
Sateen Pajama check Longcloth Nainsook Voile Crepe Broadcloth Muslin Balbriggan Outing flannel	Madras Gingham Suiting Seersucker Osnaburg Desert cloth Pique Chambray Gabardine Dotted swiss Pique voile Voile Balloon cloth Shantung	Cotton jersey Velveteen Terry cloth Corduroy Waffle cloth Pique Tweed Gabardine Drill Denim	Batiste Gingham Percale Broadcloth Suiting Crepe Dimity Organdy Lawns Waffle cloth Dotted swiss Pique
<i>Linen</i>			
Irish linen Handkerchief linen	Linen crash Handkerchief linen Dress linen Spun linen	Linen crash	Irish linen Handkerchief linen
<i>Rayon</i>			
Taffeta Knit goods Crepe Satin	Voile Crepes Pique Shantung Jersey Poplin	Moire Rep material Poplin Gabardine	Crepe
<i>Spun Rayon</i>			
	Alpaca Challis Broadcloth Gabardine Serge Seersucker Flannel		Challis Crepe Shantung Hopsacking Seersucker Batiste

Serviceability. The question of serviceability remains one on which the information needed by the consumer is conspicuously lacking. Although the breaking strength and number of ends and picks per inch of cloth are commonly accepted as determining factors in its ability to withstand the wear and tear of constant use, there are few if any clothing fabrics marketed under labels citing these items. Similarly, no information is available giving the resistance to abrasion—that is, to the friction of rubbing. This, too, would indicate wearing qualities. Lacking this the consumer buys “in the dark.”

Knitted fabrics present consumer problems different in some regards from those of woven materials. In knitted cloth perhaps the most common cause of loss to the consumer is the dropped stitch with its attendant “laddering” or running. The manufacture of warp knitting with the so-called lock stitch has made possible the purchase of knitted materials which will not “run.” Warp knitting has not as yet found common acceptance in the hosiery trade.

The fastness of color is the one factor in serviceability on which the consumer may in many instances obtain sufficient reliable information. This is particularly true of cotton goods.

To some extent, experience serves as a guide, but a constantly developing science of manufacture makes yesterday's tests and standards invalid. Recognized aids to wise consumption may be listed as guaranteed and labeled materials, branded goods, materials sold by reliable houses, and knowledge gained from our own experiences and that of others.

Silks. An examination of the fabrics on display in the silk department of a large store may be a fascinating and bewildering experience. Here we find every gradation in weight from the finest, gauzelike materials to heavy suiting; variation in texture from the softest chiffons to stiff taffetas; and every degree in luster from the dull crepes to the high-gloss satins. Color may attract us first; we find white, black, and all plain colors, and all combinations of color. In fact, every method of obtaining variety and producing both structural and surface design seems employed in the array of fabrics on

display before us. Closer examination will show that the great bulk of these silk materials are woven; many are knitted; some few may be braided.

If you wish to purchase a piece of material for a certain use, the large number of fabrics displayed will be confusing unless you can analyze your need and know the properties desired in the fabric and how these are obtained. The weave is an important factor, influencing the appearance and properties of cloth. All weaves are represented in the construction of silk fabrics, although certain weaves may be difficult to find now. At different times twill-woven silks are available in a limited variety. As you remember, plain weave furnishes strength, and satin weave gives a smooth surface suitable for lining material and undergarments and a high luster that is desirable in fabrics to be made into clothing for formal wear. Twill weave gives service, pile weave thickness, and gauze weave produces sheer, open material.

An examination of the yarn will tell you something more about the wearing qualities of the cloth. Satins are produced from slightly twisted or untwisted yarns. These will tend to catch and pull out when subjected to wear. The tightly twisted yarns used in crepe fabrics give the desired effect, reduce the luster, and produce a fabric that can stand hard wear and is often guaranteed not to crush or wrinkle. Some types of hard-twisted silk fabrics, dull in finish, become shiny with wear much as do the smooth-finished worsteds. This should be considered when selecting fabrics made from hard-twisted yarns.

Wool fabrics. The choosing of wool fabrics offers perplexing problems. We know that smooth-finished materials such as serges catch the dust less readily than do napped flannels and broadcloths. Serge is made from twisted yarns containing the best long fibers and will stand more hard wear than fabrics made from the weaker woolen yarns. But how shall we choose between two pieces of serge or two pieces of flannel by the yard or when made into garments? A guaranteed all-wool cloth may be expected to give better service than one not so labeled. If this guarantee carries the brand of a well-known

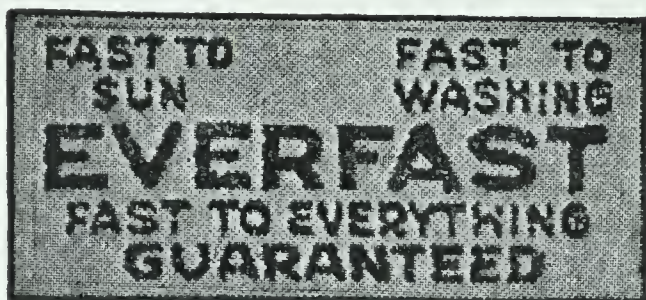
manufacturer and is handled by a reliable house we could with safety purchase the fabric. If, however, we choose wool cloth carrying no label other than that required by law and no guarantee of quality, we must depend solely upon our own knowledge to guide us. This, unfortunately, is often not sufficient. With wool, probably more than with any other material, the quality of the fiber is of prime importance, and only a microscopic or chemical test will give this information. The "lifeless" wool resulting from the destruction of the scales regardless of whether it is new, reprocessed, or reused, can seldom be detected by ordinary means, but is soon recognized after the fabric has been subjected to wear.

Cotton goods. In the case of white cotton goods we might feel more confident of our ability to judge quality by observing size, regularity, and twist of the yarn, number of ends and picks, finish, and apparent compactness of the cloth. However, it has been proved that without definite tests the determination of durability is uncertain.

Cotton material guaranteed to retain its color under all conditions of use is available on the market. Some fabrics are guaranteed against shrinkage. Other labels indicate that the finish is permanent or that the fabric is crush-resistant. These labels and guarantees are a big step in the right direction but fall short of giving information as to the wearing qualities of the cloth. Thread count furnishes an idea of quality but does not indicate strength or resistance to abrasion unless accompanied with statements concerning tensile strength or the results of abrasion tests.

The "Everfast" is a label that absolutely guarantees the fabric against any type of fading. This label is used only on cloth of high quality, so that quality is also assured. When this label was first used, many years ago, there were only seven shades of vat dyes which, when used on cloth, could be given an unconditional guarantee of fastness. Now there are innumerable vat dyes that are absolutely fast to the most severe treatment. (See the illustration on page 440.)

Linen fabrics. Linen fabrics have limited use as clothing. We have, however, the fine linens suitable for children's gar-



From *Clothing*, by Alpha Latzke and Beth Quinlan, J. B. Lippincott Co., 1935

Label in which absolute guarantee is given.

high absorptive property of linen, the lack of lint, and the ease with which it can be cleansed make it the most desirable fabric for this use. The fact that linen crushes more easily than other materials counteracts to some extent its desirable properties as a clothing fabric for outerwear unless it has been treated to make it crush-resistant.

Rayon. The selection of fabrics made from rayon presents an even more complex problem. Here we meet with all of the difficulties presented by the other fibers, together with a variation in composition and in physical and chemical properties. In fact, we have many different fibers grouped under one head.

Rayon cloth simulates the appearance of silk and may in many instances be substituted successfully for it. Each type of rayon requires special handling, hence the name of the process of manufacture is one item of information that should be furnished to the purchaser. When rayon fabrics are labeled with specifications of manufacture and directions for care, these fabrics can be purchased with more assurance that they will furnish the desired satisfaction than is otherwise the case.

Blends. With the broad development of yarns spun from staple rayons and other synthetic fibers, the problem of selection of fabrics becomes more and more complex. Staple fiber yarns spun on the standard spinning systems acquire more or less of the characteristics of the natural fiber yarns. When woven and finished as these fibers, they are detected with difficulty. Thus rayon staple fibers which are cut the length of linen fibers and spun on linen spinning apparatus, woven as

ments and for underwear. Dress linens are more or less popular at various times, and range from heavy crash suiting to handkerchief linen suitable for blouses. The handkerchief is the one article for which linen is almost universally considered to be the best fiber. The

linen, and given a noncrushable linen finish, will closely resemble an all-linen fabric. Staple fibers cut the correct length and spun on the worsted spinning system can be woven, finished, and mistaken for worsted fabric. Staple fibers mixed with the natural fibers in the spinning of the yarn add to the difficulties of selection.

In blends the combination of fibers may be done in order to reduce the manufacturing cost, but more often it is done to obtain certain desired effects that cannot be obtained with one fiber. For instance, modified rayon fibers are combined with wool in order to obtain certain stripe effects with one dyeing. Cellulose acetate rayon fibers are combined with regenerated rayon fibers in the structure of the yarn, or else yarns of the two types of rayon are combined in the construction of the cloth in order to obtain certain textural effects. A two-tone effect or a design in color is produced by correct combination of fibers that react differently to certain dyes.

Fabrics simulating standard all-wool fabrics are produced with little or no wool fibers. An expert might mistake some of the synthetic fiber fabrics for an all-silk one.

The rapid development of new synthetic fibers is adding greatly to the problems of the purchaser; Aralac, nylon, velon, vinyon or saran, and vinylidene are among the new synthetic fibers now on the market. Aralac possesses many of the desirable qualities of wool but because of its lack of strength is blended with wool or rayon in the construction of a fabric. These fabrics require special care and so should always be purchased with this fact in mind. Nylon is now being constructed into many types of fabrics and should prove satisfactory for many uses. In the past the color fastness of nylon has not been equal to that of most other materials. This fiber can be treated to resist deterioration from sunlight, and curtain and other materials that will be exposed to many hours of sunlight should be given this special treatment and labeled as so treated.

The changes and improvements that are being made with the new fibers make it impossible to give any definite information concerning their properties. Plexon is an example of

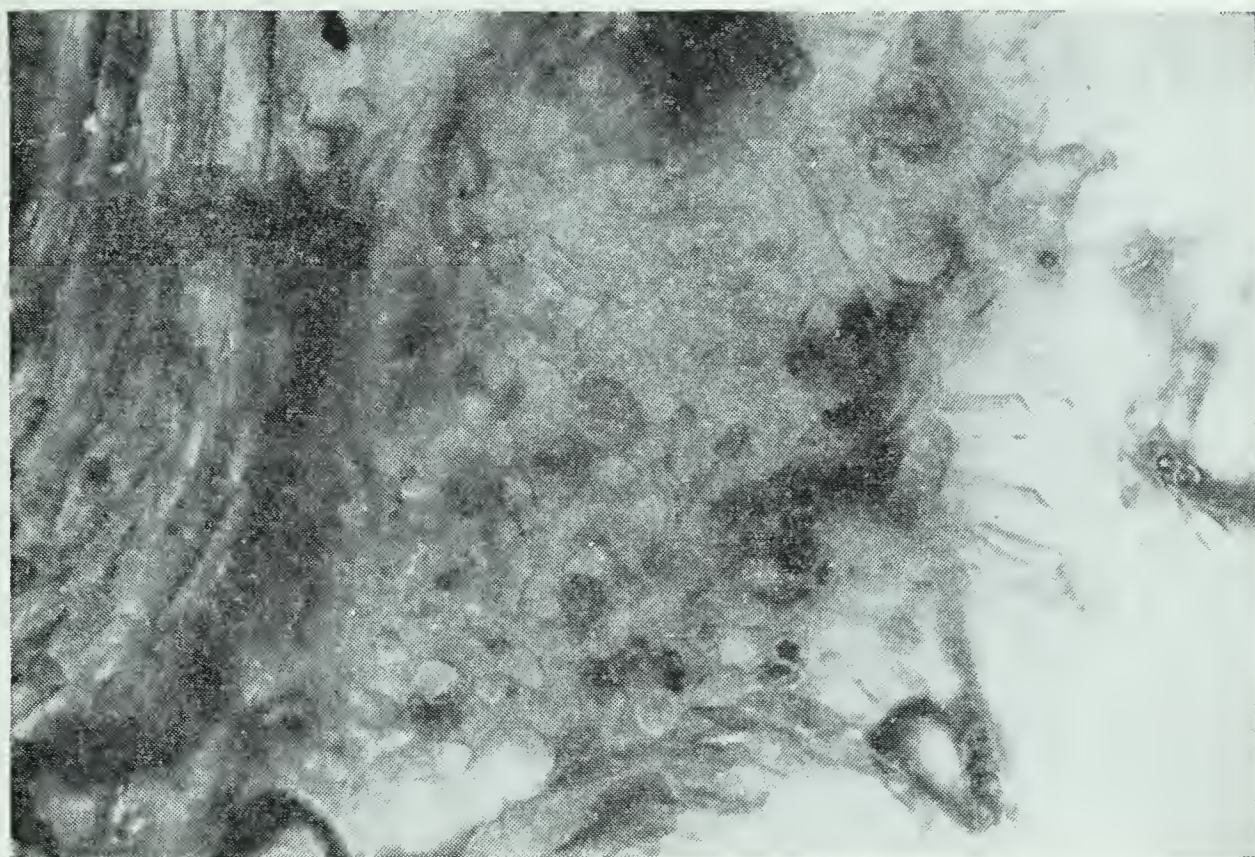
the variations it is possible to obtain with one type of material. This fabric is constructed from resin-coated yarns. Seventeen different kinds of resins are used on the various yarns, each resin imparting to the yarn its own individual properties. Thus, a fabric made from Plexon yarns may possess properties varying from inflammable to self-extinguishing, soft to stiff, absorbent to nonabsorbent, depending on the compound used as the coating. The development of many new and novel finishes adds to the difficulty of wise selection. If these finishes are permanent to wear and to the necessary mode of cleaning, then the purchaser should have no complaint; but this is not always the case.

Sufficient research has not been done to determine the effect of blending of fibers on the comparative service quality of fabrics. Hence, the substitution of fibers without proper labeling is to be questioned. The purchasers have the right to know the fiber content of the material offered for sale so that they may choose wisely and handle the materials correctly.

Almost the same difficulty is experienced in making a selection between two fabrics which, although they are constructed from the same fiber, differ greatly in service qualities. Few fabrics or garments carry labels that supply helpful information. Some rayon manufacturers are labeling their higher-grade products as made from the best quality yarn with the best quality workmanship. This should insure the purchaser a high-quality fabric, but it does not follow that another material would not be more satisfactory for a specific need. The establishment of minimum standards for service qualities of fabrics and the adequate labeling of fabrics would result in economy for both the manufacturer and the consumer. The following information resulted from a study of the accuracy of labeling fabrics made at Kansas State College.¹

The table on page 444 shows that in the case of fabrics made of a single kind of fiber, those made of cotton, linen, silk, and

¹ Hazel Fletcher and Lois Dennhardt, "The Adequacy of Labeling Certain Textile Fabrics with Regard to Fiber Content," *Journal of Home Economics*, Vol. 32, No. 1 (1940), pp. 37-39.



Cross section of mixed fabric containing fibers of wool, silk, and rabbit.

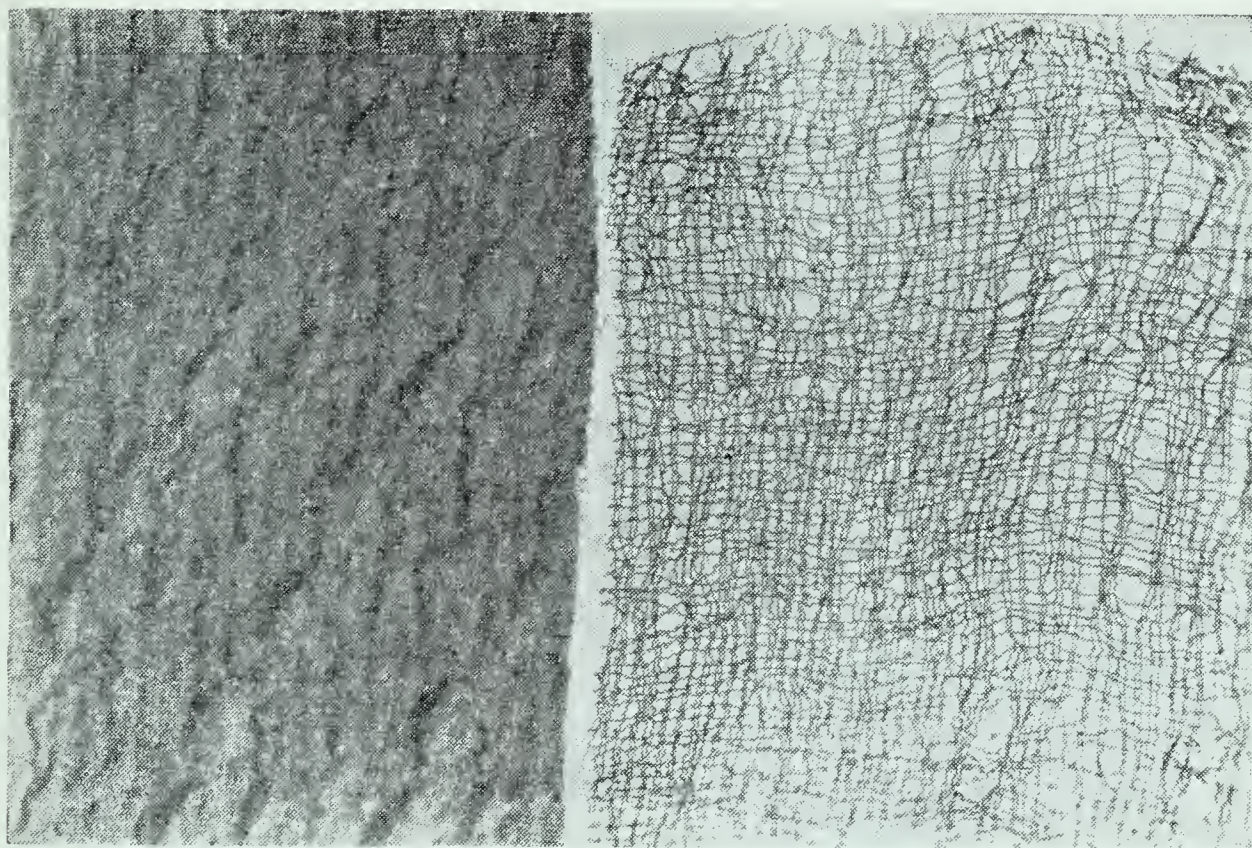
wool were commonly accurately labeled, and that when the labels told nothing as to the fiber content, salesmen, in the main, gave accurate information. The information about the three types of rayon was found to be the least accurate. These fabrics were often represented as rayon, but they were seldom specifically designated as acetate, viscose, or cuprammonium rayon. The word Celanese was often used instead of acetate; Bemberg or Bemberg rayon was always used instead of cuprammonium rayon; and rayon was used instead of viscose rayon.

Of the 133 fabrics consisting of one kind of fiber, 57 carried labels of which 23 or 40.4 per cent were accurate. Of the 79 for which salesmen gave information, 25 or 31.6 per cent were accurately described. Thus, the information on the labels was more often accurate than that given by the salesmen.

A mixed fabric was considered accurately labeled if the kinds of fibers that it contained were correctly given; for example, if viscose rayon was designated as viscose rayon or viscose, or if cuprammonium rayon was designated as cuprammonium rayon, cuprammonium, or Bemberg rayon. Where

ACCURACY OF INFORMATION OBTAINED ABOUT FIBER CONTENT OF 268 FABRICS PURCHASED ON THE OPEN MARKET [AS CHECKED AGAINST LABORATORY FINDINGS]

KIND OF FABRIC	TOTAL NUMBER	INFORMATION FROM LABELS			INFORMATION FROM SALESMEN			
		Number of Fabrics	QUALITY OF INFORMATION		Number of Fabrics	QUALITY OF INFORMATION		
			Accurate	Partially Accurate		Accurate	Partially Accurate	In- accurate
One fiber only:								
Cotton.....	4	2	2	0	2	1	1	0
Linen.....	3	3	3	0	0	0	0	0
Silk.....	26	11	11	0	16	13	2	1
Wool.....	14	5	5	0	9	8	0	1
Acetate rayon.....	16	7	1	5	9	2	7	0
Cuprammonium rayon.....	13	5	1	4	8	1	7	0
Viscose rayon.....	57	24	0	23	35	0	31	4
Total.....	133	57	23	32	79	25	48	6
Mixed fibers:								
Cotton and wool.....	11	2	0	2	11	4	5	2
Cotton and viscose.....	15	3	0	3	13	0	11	2
Cotton and linen.....	6	5	0	5	2	0	2	0
Wool and rabbit fur.....	3	0	0	0	3	1	2	0
Wool and viscose.....	21	4	0	4	19	0	18	1
Wool and silk.....	5	2	0	2	5	1	4	0
Silk and viscose.....	7	2	0	2	5	0	5	0
Acetate and viscose.....	43	12	0	12	31	0	30	1
Other combinations of 2 kinds of fibers.....	6	1	0	1	5	2	3	0
Other combinations of 3 kinds of fibers.....	18	3	0	3	16	1	14	1
Total.....	135	34	0	34	110	9	94	7

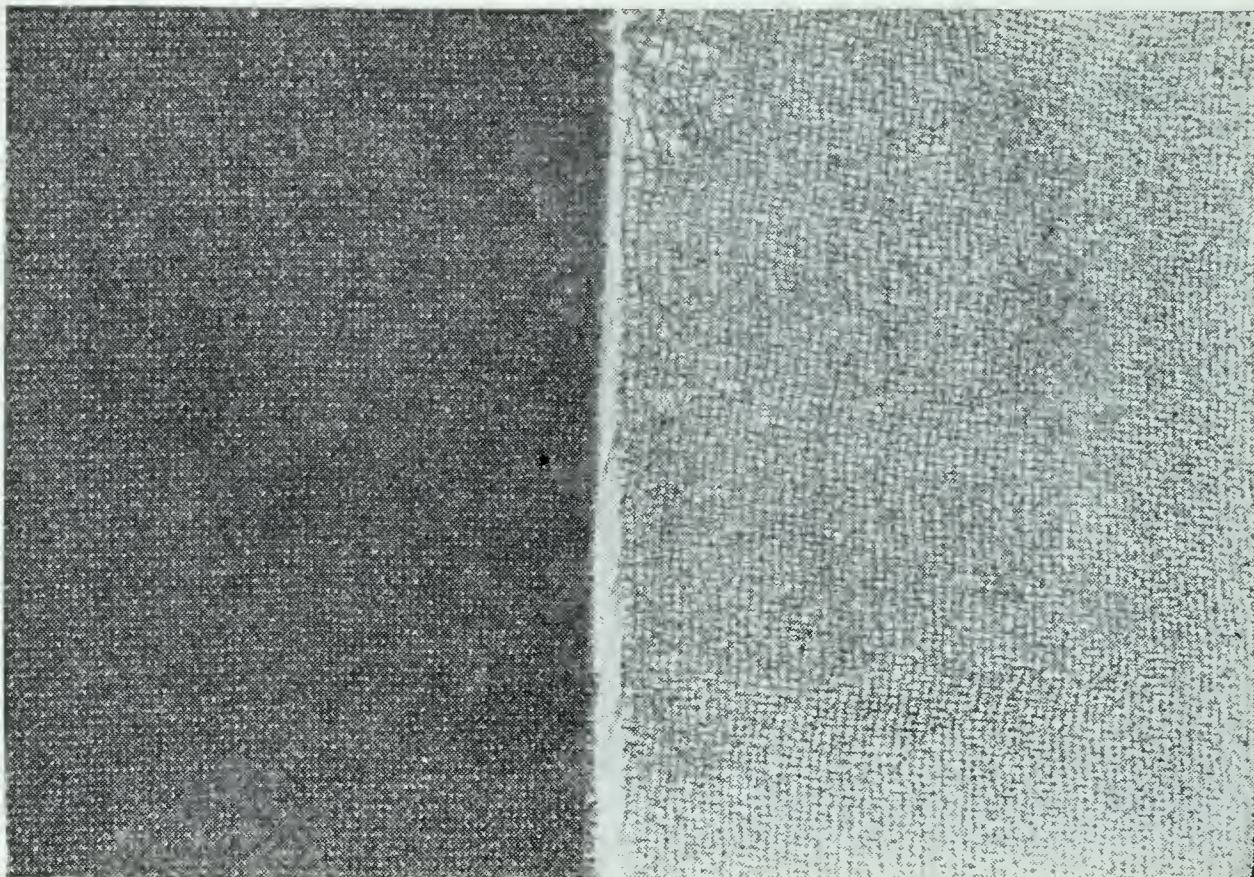


Mixed fabric: 69 per cent acetate, 31 per cent viscose. The cellulose acetate in this mixed fabric was removed with acetone, leaving only a thin fabric of viscose rayon.

the percentages of the various fibers were stated, the information was considered accurate if the figures were correct within 10 per cent and partially accurate if the percentage of one kind of fiber was given and not the others.

Of the 135 mixed fabrics, 117 were made of two kinds of fibers, and 18 of three kinds. Many had warp yarns of one kind and filling of another; others were made of blended yarns; still others were of ply yarns of different fibers. Cellulose acetate rayon and viscose rayon were most frequently found in combination.

Neither the labels nor the salesmen gave much information concerning the percentage of each fiber present. Moreover, only one label was found that stated the percentage of fiber present; this gave the wool content of the fabric as 25 per cent, but analysis showed only 15 per cent. The clerks gave percentages of fiber content for 12 fabrics, of which one was accurate, 10 partially accurate, and one wrong.



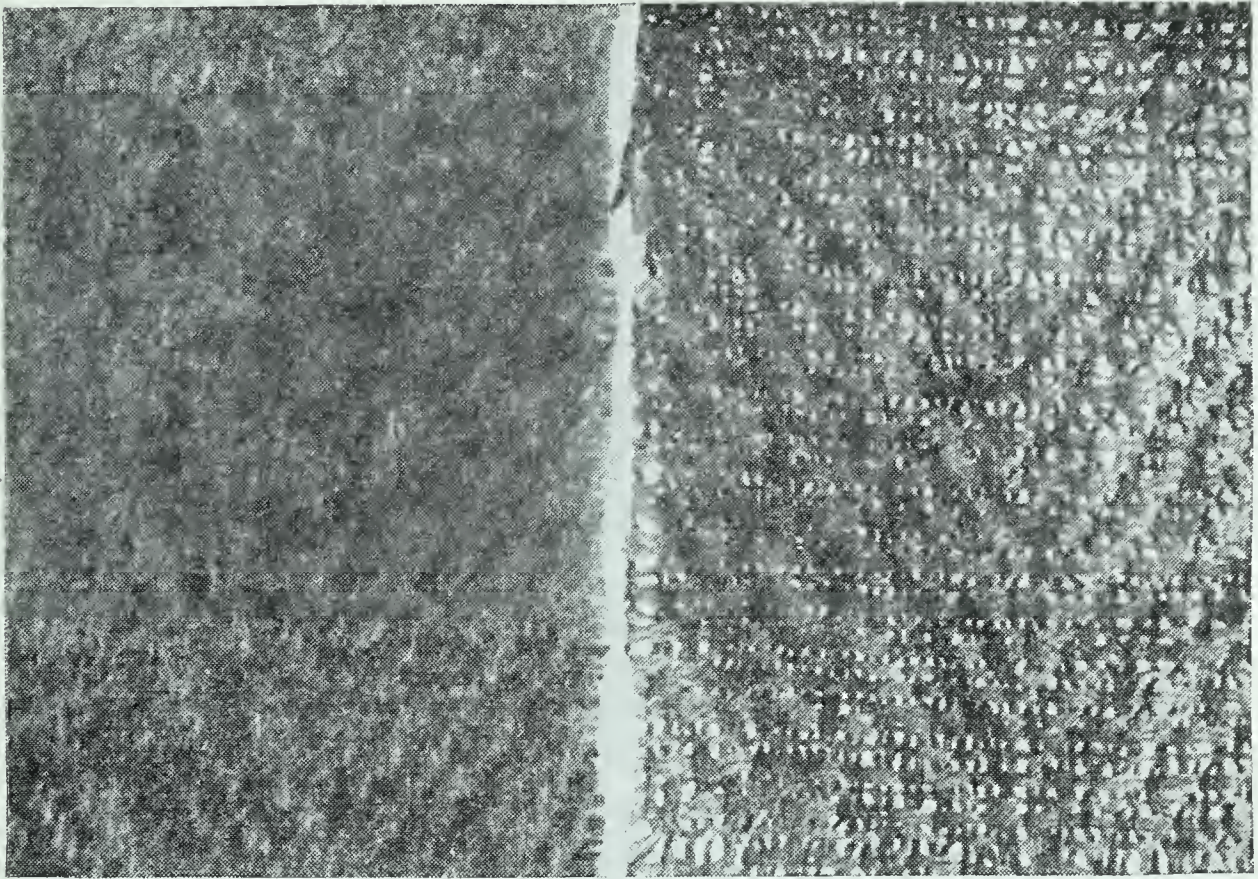
Mixed fabric: 55 per cent viscose, 45 per cent wool. The wool in this fabric was removed with 5 per cent solution of boiling NaOH.

Of the 135 mixed fabrics examined, only 34 were labeled; and for all of these the information given was only partially accurate. The clerks gave information concerning 110 fabrics. This was accurate in the case of 9 or 8.2 per cent, partially accurate in 94 or 85.4 per cent, and wrong in 7 or 6.4 per cent.

PROBLEM 2. WHAT SHOULD DETERMINE THE CHOICE OF DRAPERIES AND SIMILAR FABRICS FOR THE HOME?

Suitability. If you were to survey the hangings, draperies, and upholstery in the homes of your community, you would doubtless find a wide variety of colors, designs, and fabrics.

A list of fabrics used for draperies, curtains, and upholstery would be long and varied. In general, a member of the home or the owner of a room finds ready channels for self-expression in the character of material chosen for these articles. The fabric is usually selected to meet certain needs of the individ-

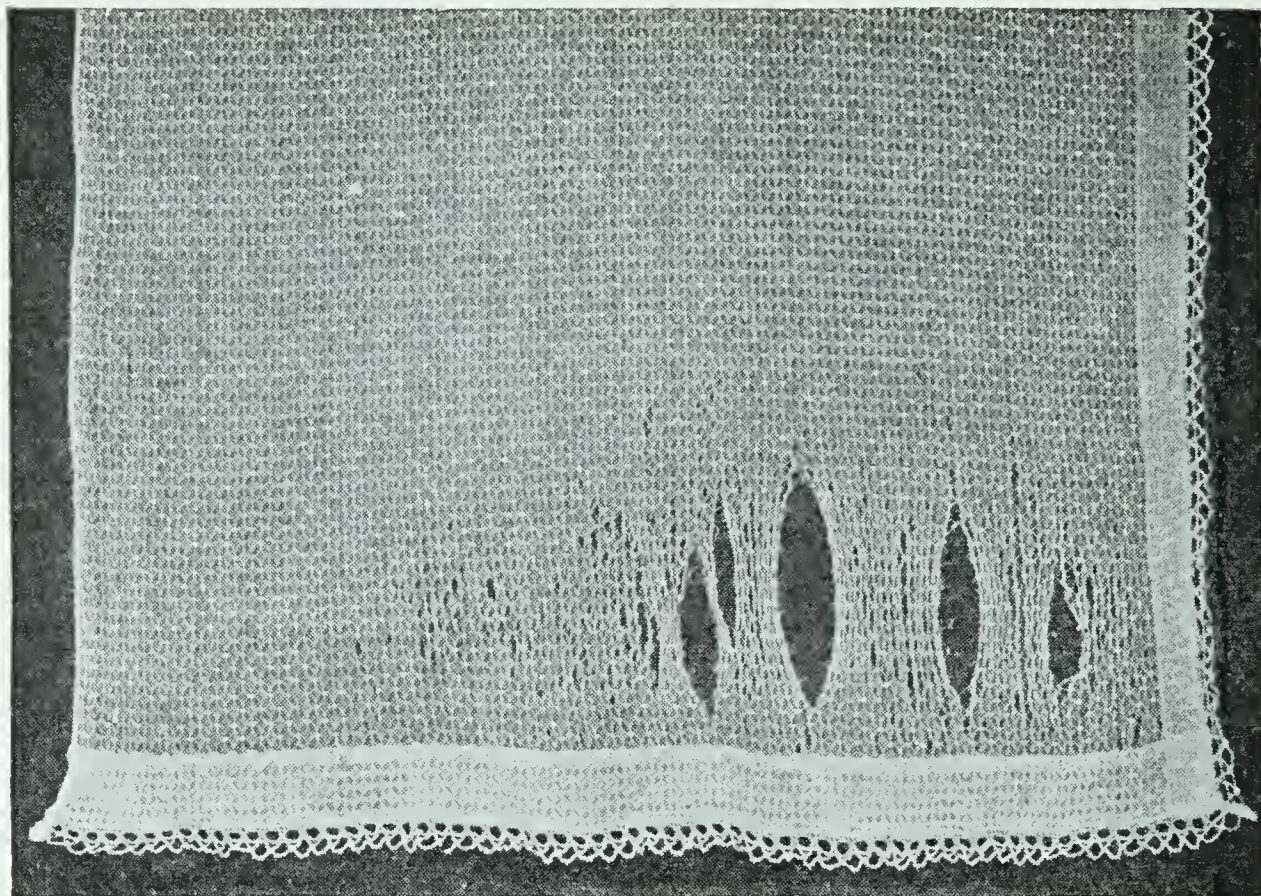


Fabric containing 42 per cent viscose and 58 per cent wool. The wool has been removed, leaving only the rayon.

ual or family. Window hangings are often required to achieve the apparently diverse ends of letting in sunlight and air, and yet excluding the world outside so as to afford privacy for the individual. Not infrequently the further demand is made that they introduce color into the room.

Perhaps the simplest treatment of windows is with one set of curtains only. In this case the cotton materials frequently used are scrim, marquissette, voile, or swiss. Theatrical gauze is one of the few linen fabrics used for this purpose. Rayon is found alone or in combination with cotton in voiles and marquissettes. Occasionally pongee or china silk is used for curtains. Nylon, marquissette, and woven and knitted fabrics of Fiberglas are among the newer curtain materials now available. Why are wool curtains not common? Some of the sheerer fabrics serve as glass curtains covering the entire window, in connection with overdraperies of heavy material.

Gauze-weave fabric is especially suited for glass curtains. Both braided and knitted nets also are available for this pur-



Courtesy Laundryowners National Association of the United States and Canada

Tendering effect of sunlight on curtains.

pose. These fabrics, though light in weight and having large interstices, must be made from firm and well-twisted yarns that are all of comparatively the same size; if a small, inferior yarn is constructed into a fabric, it weakens the whole piece.

Structural design, produced by a combination of weave, yarn, fiber, and color, is largely used in drapery fabrics. In the choice of such materials one must be guided by the factors influencing the durability of cloth. Fabrics in which the designing yarn forms long floats on the back are not practical unless lined to prevent wear on these loose yarns.

Not only structural design, and surface design in the form of print goods, but also solid colors are found in drapery materials. In the use of curtains and hangings there is the special problem involved that, in the nature of the case, the fabric must be exposed to air and dust, and sometimes to moisture and to sunlight, direct and indirect. The effect of these on any fabric is determined in part by the nature of the fiber. What effect does sunlight have on silk; on cotton; on rayon? Would

you consider the exposure of the room when deciding the fiber and fabric to be chosen for draperies? Why? (See the illustration on page 448.)

Again, the exposure to these elements may affect the color of the fabric. Today it is possible for the consumer to purchase materials guaranteed for the life of the fabric to be fast to both sunlight and water. The purchase of draperies or colored curtains without the security of this guarantee would indeed be poor judgment.

A study of the effect of exposure to light on the breaking strength of two qualities of cotton, one rayon and one nylon curtain marquisette, indicated that the nylon fabric resisted deterioration by light to practically the same extent as did the better grade of cotton fabric, but the rayon fabric deteriorated about $3\frac{1}{2}$ times as much as did the cotton or nylon fabrics. Specimens of the four types of marquisette were exposed for 40, 80, and 120 hours in a standard type of Fadeometer set at 100° F. Results of exposure for 120 hours are given below:

FABRIC	PRICE PER YD.	WIDTH	PER CENT DETERIORATION
Cotton.....	\$0.35	36"	11.5
Cotton.....	1.00	36"	4.0
Rayon.....	1.19	42"	14.3
Nylon.....	1.25	36"	4.3

The nylon was dark brown in color and faded badly, with 120 hours of exposure. The other pieces were white and showed no evidence of discoloration.

These same fabrics were tested for the relative amount of shrinkage and for their ability to be restored to original size. This work was done in a Restorability press manufactured by the United States Testing Co., Hoboken, New Jersey. The fabrics were washed by hand and dried on a flat press and then measured for shrinkage. They were then wet thoroughly and weights applied according to the percentage of shrinkage. Directions accompanying the apparatus state that any fabric that cannot be restored to within two per cent of its original

size is considered not satisfactory for laundering. The results of these tests showed that the cheap cotton and the rayon marquisette, neither of which was labeled, shrank so much that they would not be considered satisfactory. The better grade of cotton fabric labeled as *shrink controlled* and the nylon each shrank less than two per cent.

An all-silk drapery fabric is not now available at a reasonable price and authorities predict that silk fabrics will remain in the luxury class for many years. Some fabrics in which raw silk or spun silk is used are available in various forms. Cloths made from cotton, rayon, nylon, or other fibers used alone or blended are shown in many novel and effective forms, some of which used silk.

Not infrequently cushions and table runners are added to introduce decorative notes or desired color. In general, the heavy fabrics suitable for draperies may serve for such purposes. There are, however, additional problems of wear and soil to be considered. A firm fabric is absolutely essential to withstand the wear and the necessary cleaning. When choosing fabrics for curtains, draperies, or cushions for a specific need there are many factors to be considered. The purpose of the room in which they are to be used is probably the first consideration. For example, elaborate, heavy silk or rayon draperies would be impractical in a simple home of the bungalow type, for which linen or cotton homespun fabrics would be suitable.

Cost. In the selection of these household fabrics, as in the selection of clothing materials, the amount of money to be expended influences choice. There is a wide price variation in the fabrics available. The offerings of a drapery department show a range from imported, hand-blocked linens and velvets at \$12 to \$25 a yard, down to printed cretonnes at 39 cents a yard. Even after the price level has been rather definitely determined, the purchaser is often bewildered by the kinds and types of materials offered at the price set.

The use of synthetic fibers alone or in connection with other fibers in the production of drapery fabrics has made possible beautiful decorative material at a lower price. Rayon

may have a high luster or be lusterless; or it may possess a combination of these qualities. Different types of rayon are combined to obtain certain novel effects. Contrary to general opinion, with the exception of certain underwear materials, silk and rayon are seldom combined in the construction of household or clothing fabrics.

To secure the best fabric for the money is not a simple matter. Sometimes a novel or bizarre design will be offered at a price far in excess of its actual worth in wearing qualities. The additional cost is added because of the prevailing fashion. Not infrequently the price of a fabric is markedly reduced because the stock is being closed out, or a surplus is being disposed of. These matters in no way affect the value of the material.

The length of time that hangings of any kind may be expected to retain their freshness and so give satisfaction to the user may well be considered in the original cost. Because of the labor necessary to construct them satisfactorily, fabrics that are so extreme in color or design or possess so little wearing quality that they must soon be replaced are expensive, no matter what their initial cost.

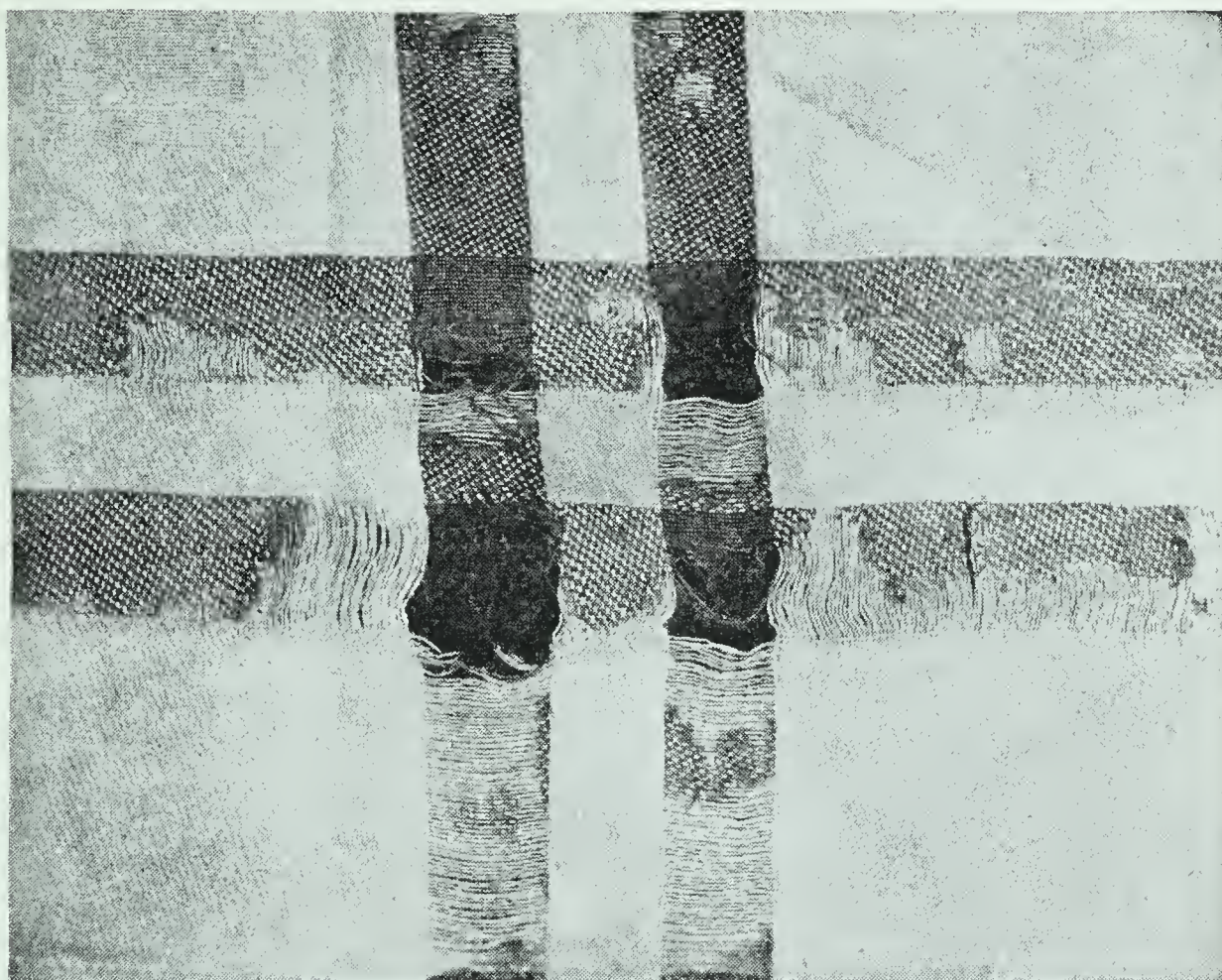
PROBLEM 3. HOW SHALL TABLE LINEN AND TOWELS BE SELECTED?

Our linen problems differ less widely from those of our grandmothers than might seem to be the case. Grandmother may have raised the flax, and have spun, woven, and bleached the fabric from which she made her tablecloths, napkins, and other linen articles used in the home. She knew that the long line fibers, when properly retted and spun into smooth yarns, would produce a high-luster fabric that always remained a beautiful white. Yarns spun from the short tow fibers tended to be rougher, and cloth made from these had protruding ends that reduced the luster and lessened its beauty. Today we have but to select and purchase the article that someone else has produced, but we, too, must know what effect the type of fiber, the size and twist of the yarn, the construction, and

the finish have on the properties of cloth; and we must be able to select the material that will meet our individual requirements. Here, probably more than with most materials, we need the assistance of a definite fabric analysis to guide us in our choice.

It is difficult to determine the kind of fibers used in the formation of yarns in yard goods, and almost impossible to learn anything about ready-made articles. A few washings will remove starch or other soluble dressing from fabrics, and thus leave cloth of this type sleazy and lighter in weight than was supposed. The number of ends and picks per inch, the weight of the fabric, and the percentage of dressing furnish a good index to quality, but these facts are difficult to obtain. Even the experienced purchaser can with difficulty detect mercerized cotton when mixed with linen in the construction of the yarn. When new, an all-mercerized cotton cloth given a linen finish simulates the appearance of linen, but laundering may destroy its high luster and smooth finish. These cloths usually leave lint on fabrics coming in contact with them and may be objectionable because of this. They are, however, comparatively inexpensive and retain their proper shape when run through an ironer or when sent to the commercial laundry. Under some circumstances a mercerized cotton cloth will be satisfactory and is to be preferred to an inferior quality of linen cloth.

Cotton table damasks are usually figure weaves produced by the combination of satin and sateen or twill weaves. Although the pattern is flat and usually all one color, the design stands out distinctly because of the contrasting light reflections from the floating yarns. Some table damasks have colored borders or are woven from vat-dyed warps and white filling yarns. The cotton damasks are given either a calendered, schreinerized, or mercerized finish. A permanent linen-like finish is used on the better quality of cotton damask. It gives a smooth finish that eliminates lint and the necessity for starching. Cotton damasks are usually single damask four or five harness and vary in thread count from 62 x 48 to 80 x 76; however, they are sometimes constructed in the double dam-



Courtesy Laundryowners National Association of the United States and Canada

White cotton tablecloth with colored border. Weakened yarns showing effect of dye.

ask weave, which is an eight-harness construction. This type is finer quality and has a higher thread count—about 96 x 104.

Cotton and rayon are mixed in the construction of table damask, using the cotton as warp and the rayon as filling; or rayon filament yarns in white may be combined with colored mercerized ply yarns. The rayon and cotton may also be combined in white and colored designs.

A study of table napkins of all-linen, all-cotton with and without a permanent finish, and a cotton and rayon blend showed that the rayon deteriorated the least of the fibers during wear and laundering through a 32-week test period.¹ The permanent-finished cotton yarns deteriorated less than the cotton yarns without this finish and the linen yarns were the

¹ Lottie E. Sumner, and Elizabeth D. Roseberry, "Serviceability of Linen, Cotton with a Permanent Finish and Rayon-Cotton Table Napkins." *Rayon Textile Monthly*, 25 (1944), pp. 53-6.

least serviceable judged on a basis of loss in breaking strength, weight, and appearance. Shrinkage in actual service was much greater than that obtained in five laboratory launderings. By both methods the cotton fabrics shrank more than the linen ones and in the fabric made of cotton warp yarns with a rayon filling the shrinkage was slightly greater in the warp than the warp in the all-cotton fabrics. The rayon and cotton fabrics varied greatly in the filling shrinkage, but, with the exception of one fabric in which there was no filling shrinkage, the shrinkage of the rayon-filling yarns was greater than the filling shrinkage of either the all-cotton or all-linen fabrics.

The results of this study would tend to prove that rayon blends in table napkins are superior to all-linen or all-cotton napkins.

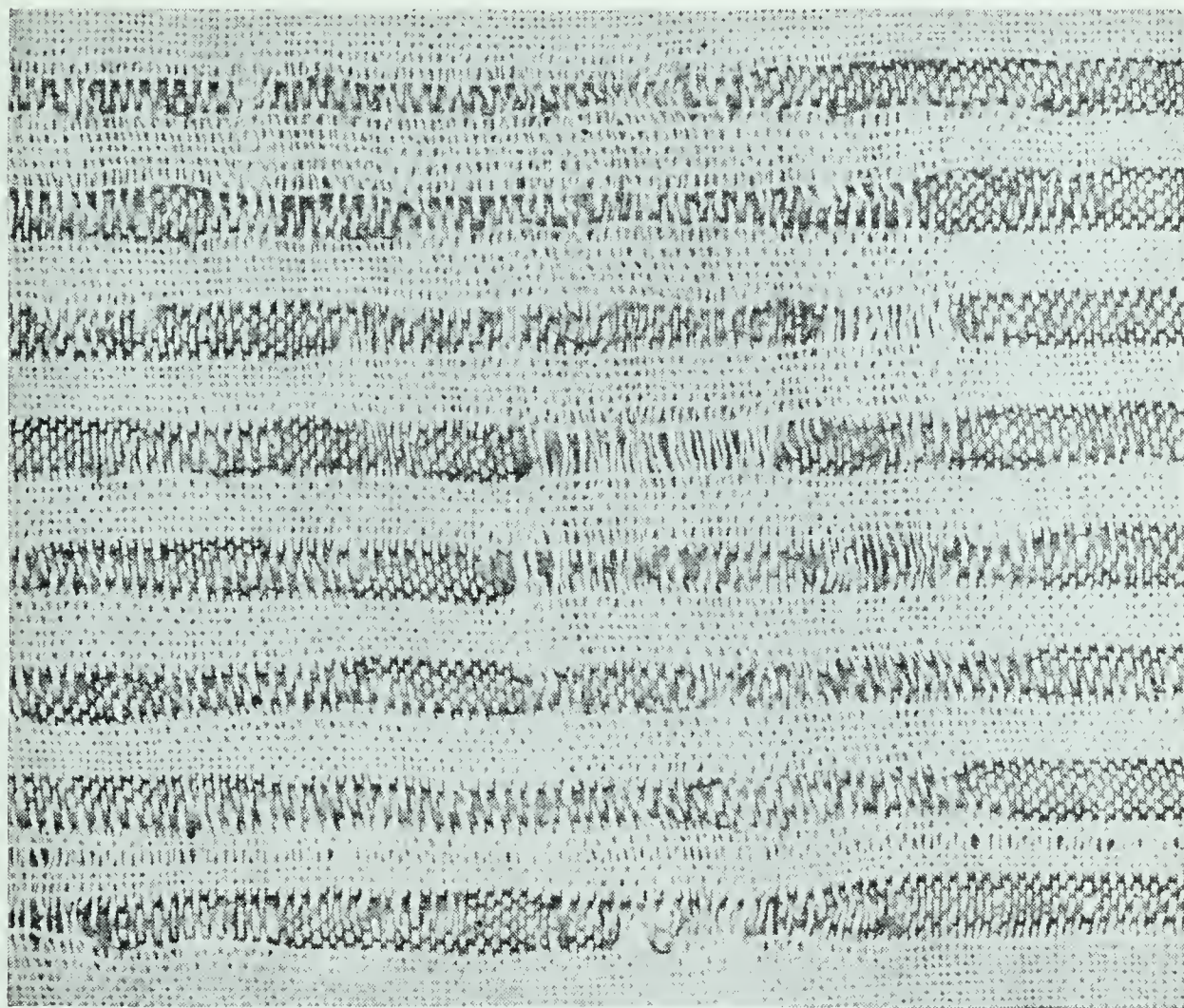
Table damasks are sold in the following widths: 36, 45, 54, 58, 64, 72, 80, and 90 inches. Tablecloths are sold in various sizes, such as 36 x 54, 45 x 54, 54 x 54, 64 x 72, 72 x 90, and 90 x 108 inches.

Napkins vary greatly in size. They are usually square but may be from 13 to 24 inches square. Dinner napkins usually match the cloth and may be from 18 to 24 inches square.

Fabrics composed entirely of cotton in white and colors are available in small luncheon cloths and napkins for everyday use. These may give good service and prove satisfactory, but sometimes the colored yarns are weaker than the white ones. (See illustration on opposite page.)

Linen damask. Linens of fine quality have distinction and beauty. They usually represent a large expenditure of money and their care requires considerable time. The tendency to have only a part of the meals served in the home and to entertain guests outside the home has reduced the number and size of table linens frequently used. The meals served at home are often of such informal nature that there is a growing tendency toward the acceptance of the use of luncheon sets and small pieces of linen for the table. These luncheon sets may be obtained in attractive colors and designs.

Tablecloths may be made from yard goods or pattern cloths, or bought as finished articles. A finished tablecloth will cost



Courtesy Laundryowners National Association of the United States and Canada

The green and black yarns in this tablecloth were about one-sixth as strong as the white ones.

more than a pattern cloth of the same quality; and cloth by the yard will be less expensive than either finished cloth or pattern cloth. Lovely fabrics may be obtained in all white or in colors; in all linen or linen combined with rayon. The width of table linen is indicated as quarter yards, increasing in quarter-yard widths to two or two and one-half yards. In purchasing material for a table, six or more inches must be allowed on each side and allowance must be made for hems and shrinkage. Pattern cloths should be chosen to fit the table. Sizes of napkins vary according to occasion and individual taste but tend to follow the trend of reduction in size. An accepted size for dinner napkins is twenty to twenty-two inches; for breakfast, eighteen to twenty inches; and luncheon and tea napkins may be as small as twelve inches. It is well to con-

sider the tastes of the household, and when selecting remember that some people do not like small napkins.

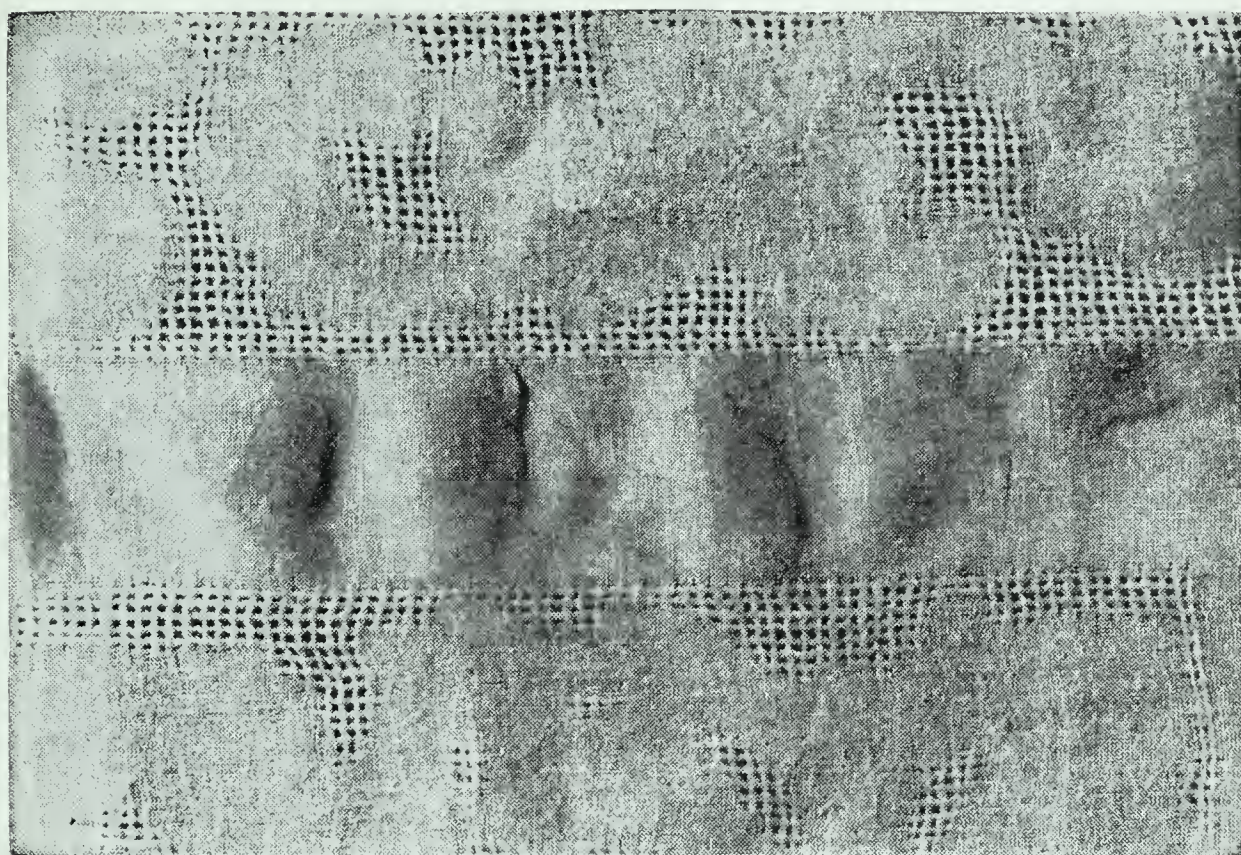
The quality of linen fabrics is determined by the quality of the yarn and the type of weave. A smooth linen yarn free from lumps and thick places is necessary for the construction of a cloth of good quality. A combination of satin and sateen or of two twill weaves is used to create design in table linens.

These cloths are woven in what is known as a double and a single damask. According to Mr. R. F. Beech of William Liddell and Co., Belfast, Ireland, and New York City, the terms *double* and *single damask* indicate the difference in the type of loom used in their construction. The number of warp and filling yarns is approximately the same in a single damask. The number of filling yarns exceeds the number of warp yarns in a double damask, and in this fabric the yarns are packed much more closely together. "Double damask means that only every eighth thread is bound down by the shuttle in going across the loom."¹ One hundred and seventy-five yarns per square inch is the maximum number of ends and picks used in the construction of a single damask. One hundred and eighty-five yarns per square inch is the minimum number of yarns that can be used in a satisfactory double damask. In this cloth there should be one and a half times as many filling yarns as warp yarns.

A single damask of good quality will wear longer and be more satisfactory than a low-count double damask because in a low-count double damask the floats are too long.

The weight selected is a matter of choice, but usually a medium weight is preferred for general use. Under six ounces per square yard is considered light weight. Cloths that are finished with a high percentage of dressing will lack body after laundering. Other fabrics tend to seem heavier after laundering and may not prove to be the fine fabrics desired. Because it is most difficult to determine these qualities in linens, it is wise to buy guaranteed fabrics from a reliable house.

¹ R. F. Beech, "Linens—What to Buy and Why," *Hotel Monthly*, Vol. 43 No. 509 (1935), p. 16.



Tablecloth in which the difference in weaving resulted in uneven shrinkage.

Tablecloths and napkins of plain weave with a border or design in basket weave often prove unsatisfactory because of unequal shrinkage of the fabric. The loose basket weave draws up so that the cloth cannot be ironed smooth. A fabric of this type is shown in the illustration above.

The beginnings of specifications are seen in the methods used by large concerns. One food service, whose purchase of linens runs into hundreds of dozens, bases its selection on the following specifications:

SPECIFICATIONS

Napkins 24" x 24"

Greek Key and Leaf Design

Table Cloths 54" x 54"

Table Cloths 54" x 68"

Pure Fresh Linen. Oak Leaf Pattern, Crest.

1. A. The linen furnished on this requisition must be guaranteed by contractor to be of high grade double damask linen, made entirely from pure flax line yarns with no admixture of

tow yarn, jute, hemp or other substitutes. B. The fabric shall be evenly woven and shall be free from knots, slubs or other imperfections which would affect the appearance or serviceability of the goods. All pieces must present a clear, evenly woven appearance when held to light.

2. Design. Table Cloths of Oak Leaf Design and Crest. Napkins Leaf and Greek Key. Each piece shall have woven into the edge "36" indicating the year of manufacture.

3. Finish and Bleach. All linen delivered under this specification shall be grass bleached white, with no discernible residue of caustic in the finished article. The fabric shall contain no free or excess starch or other filler and the fabrics shall be at least 95 per cent of the weight of the finished product. No starch, chalk, gum arabic, or any other artificial binder is to be used upon the linen delivered under these specifications. The linen shall have a blue white or milk white appearance and be soft, smooth, and pliable.

4. Hemming, size, etc. The hemmed finished sizes shall be as follows:

	WARP	WEFT	TOTAL COUNT PER SQ. IN.	WEIGHT PER SQ. YD.
Napkins 24" x 24"	96	121	217	7-oz.
Cloths 54" x 54"	96	121	217	7-oz.
Cloths 54" x 68"	96	121	217	7-oz.

A minus tolerance of 5 per cent will be permitted in the count of the warp or in the count of the weft, provided the combined count is not less than the total count specified above. All goods furnished under this specification will be truly rectangular and of the finished sizes specified. Each piece shall have a $\frac{3}{8}$ inch hem (on each side of the cut sides) which shall be of uniform width and sewn with pure flax linen thread with not less than 18 stitches per inch. The corners shall be backstitched and locked. The cut edge to be folded under the exposed hem so as to constitute three folds of cloth.

5. Tensile strength shall be as follows:

	WARP	WEFT	TOTAL
Napkins	120 lbs.	160 lbs.	280 lbs.
Cloths	120 lbs.	160 lbs.	280 lbs.

A minus tolerance of 10 per cent will be allowed in the strength of the warp or in the strength of the weft, provided the

combined strength of the warp or weft is not less than the total given above. Tensile strength shall be determined by the "strip method," as used and approved by the United States Bureau of Standards in determining the tensile strength of fabrics.

6. Packing. All linen shall be packed in substantial wooden shipping containers in such a manner as to prevent injury during shipment. Containers shall be marked with the name of the contractor, name of manufacturer, order or register number under which delivery is made, and exact name of contents and number of pieces contained.

The following is taken from DDD-L-391a, August 19, 1936:

FEDERAL SPECIFICATION FOR LINEN: TABLE (DOILIES, NAPKINS,
AND TABLECLOTHS)

D. General Requirements.

D—1. *Tolerances.*

D—1a. *Thread Count.* A combined minus tolerance of 4 threads per inch and any plus tolerance will be allowed, provided that the total count is not less than 173 threads per square inch.

D—1b. *Dimensions.* A tolerance of plus or minus 2 per cent will be permitted.

D—1c. *Weight.* A minus tolerance of $2\frac{1}{2}$ per cent, and a plus tolerance of 5 per cent will be permitted.

E. Detail Requirements.

E—1. *Finish.* The material shall be fully bleached. The sizing will not exceed 5 per cent of the total weight.

E—2. *Thread Count.* The threads per inch shall be not less than 94 in the warp and not less than 79 in the filling.

E—3. *Dimensions.* The dimensions shall be as specified. All goods shall be truly rectangular.

E—4. *Weight.* The weight per square yard shall be 6 ounces.

E—5. *Breaking strength.* The minimum breaking strength (strip method) shall be 115 pounds in the warp and 120 pounds in the filling.

E—6. *Weave.* The weave shall be single damask, known to the trade as 5-leaf twill construction. Patterns for types A and B will be chosen from the contractors' standard patterns. The design of types C, D, E, and F shall be as specified.

E—7. *Hems.* Types A, B, and C shall have a $\frac{1}{4}$ inch hem

on each of the cut sides. All corners shall be over and back stitched and locked.

Towels. The availability of towels of every shape, size, and color, varying in cost from a few cents to a few dollars, should cause the purchaser to study well her individual problem before making a selection. Linen, because of its higher absorptive power, its ability to give up moisture quickly, and its ease in being kept white, makes an ideal material for towels. It is not always wise or possible to have linen for all uses.

Hand and face towels. Hand and face towels may be all linen, linen and cotton, all cotton, or cotton and rayon. They vary in weave, being plain, twill, satin, or figure. Honeycomb, huckaback, bird's-eye, and small geometric designs are usually shown in linen or cotton and in a combination of these. The wearing quality and softness of the towel are influenced more by the kind of fibers, the variation in the size and twist of the yarn, and the number of ends and picks per inch than by the variation in the weave. The lovely, soft damasks are usually made from a soft linen yarn that is not so strong as that used in the twill weaves. The colored borders and rayon yarns may add to the attractiveness but do not increase the wearing qualities. Hand towels vary in size from a small towel fourteen by twenty inches or less to one twenty-seven by forty-two or more inches. The size influences the price to a great extent, towels of the same quality usually increasing in price proportionately with the increase in size. Small towels are preferable for individual use, as generally only the center of a large towel is used.

Lacking informative labeling concerning wearing qualities, one must base selection on price, size, and appearance. If towels were labeled with specifications similar to those that follow, wise selection would be less difficult.

FEDERAL SPECIFICATION FOR CRASH TOWELS (No. 633)

Types or Grades

1. Types. The material covered by this specification shall be furnished in the following types, as specified:

Type A. Crash Toweling.

Type B. Crash Towels.

2. Grade. The grade shall be that known commercially as "firsts."

Material and Workmanship

The material shall be made of cotton warp and linen filling. It shall be free from avoidable imperfections of manufacture and from defects or blemishes affecting the appearance or serviceability.

GENERAL REQUIREMENTS

1. Finish. The materials shall be scoured, but unbleached and undyed, except that colored lines $\frac{1}{4}$ inch wide may be woven in about $\frac{1}{2}$ inch from each selvage.

2. Weave. The material shall be plain woven.

3. Width. The material shall be 17 inches wide. A tolerance of plus or minus $\frac{1}{4}$ inch will be permitted.

4. Weight. The weight per square yard shall be 6 oz. A minus tolerance of 3 per cent, and any plus tolerance, will be permitted.

5. Thread Count. The threads per inch shall be 28 in the warp and 22 in the filling. A minus tolerance of 2 threads in the warp and one thread in the filling, and any plus tolerance, will be permitted.

6. Breaking Strength. The minimum breaking strength (grab method) shall be 45 pounds in the warp and 35 pounds in the filling.

Bath or Turkish towels. Terry woven cotton towels are universally used for bath towels because their soft looped surface readily absorbs large amounts of water. It is recorded that the first fabric with a looped surface was made by the women in the Turkish harems from loosely constructed plain woven fabric. These women carefully pulled the yarns into loops on the surface of the cloth for fabrics to be worn as a head dress. A fabric prepared in this way served as the inspiration for the construction of machinery that could weave this type of cloth.

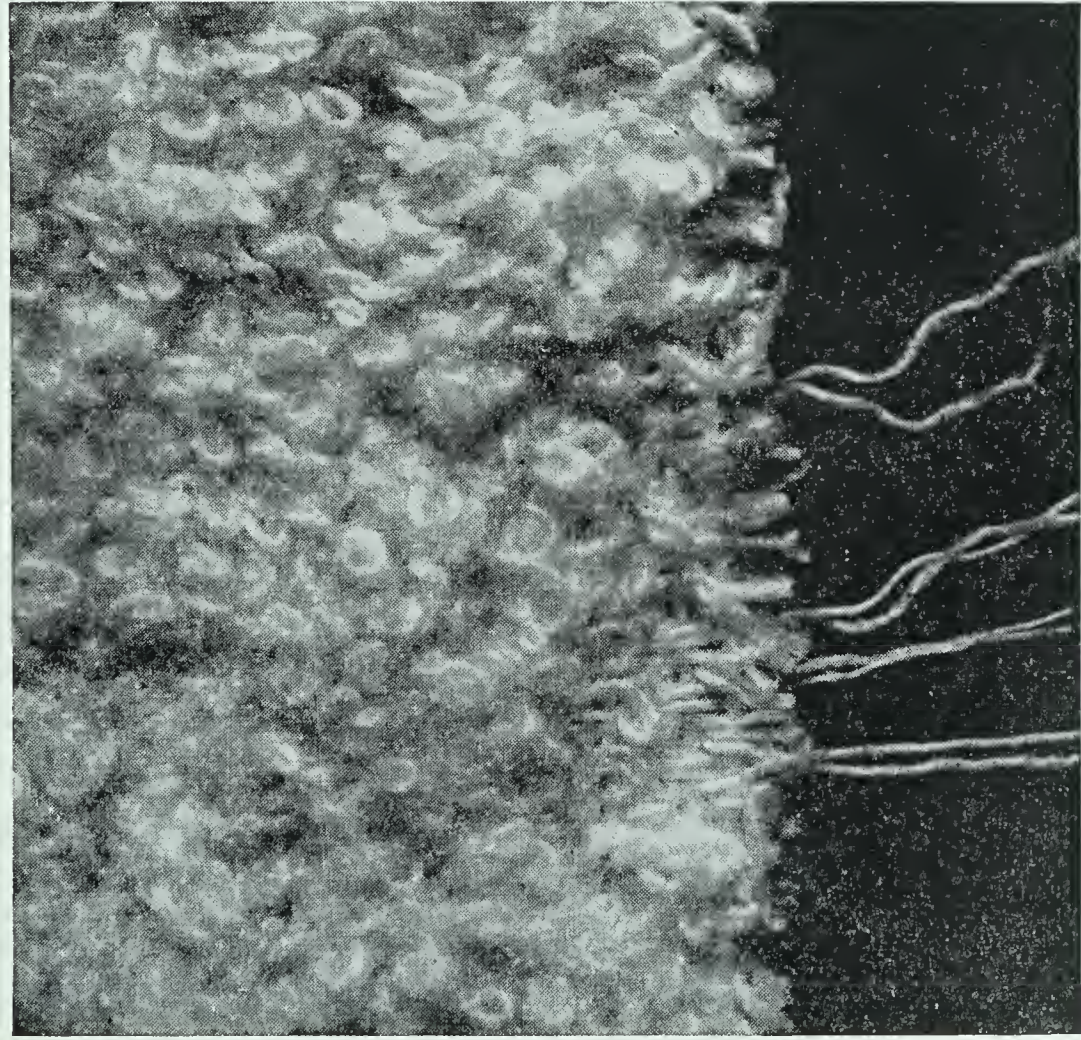
The availability of bath towels of every shape, size, and color, varying in cost from a few cents to a few dollars, should cause the purchaser to study well the problem before making

a selection. The first question to consider is: What are the qualities desired in a bath towel for home use? Durability and the ability to absorb moisture rapidly should be the first qualities to consider, but unfortunately many towels are selected on the basis of appearance and price only.

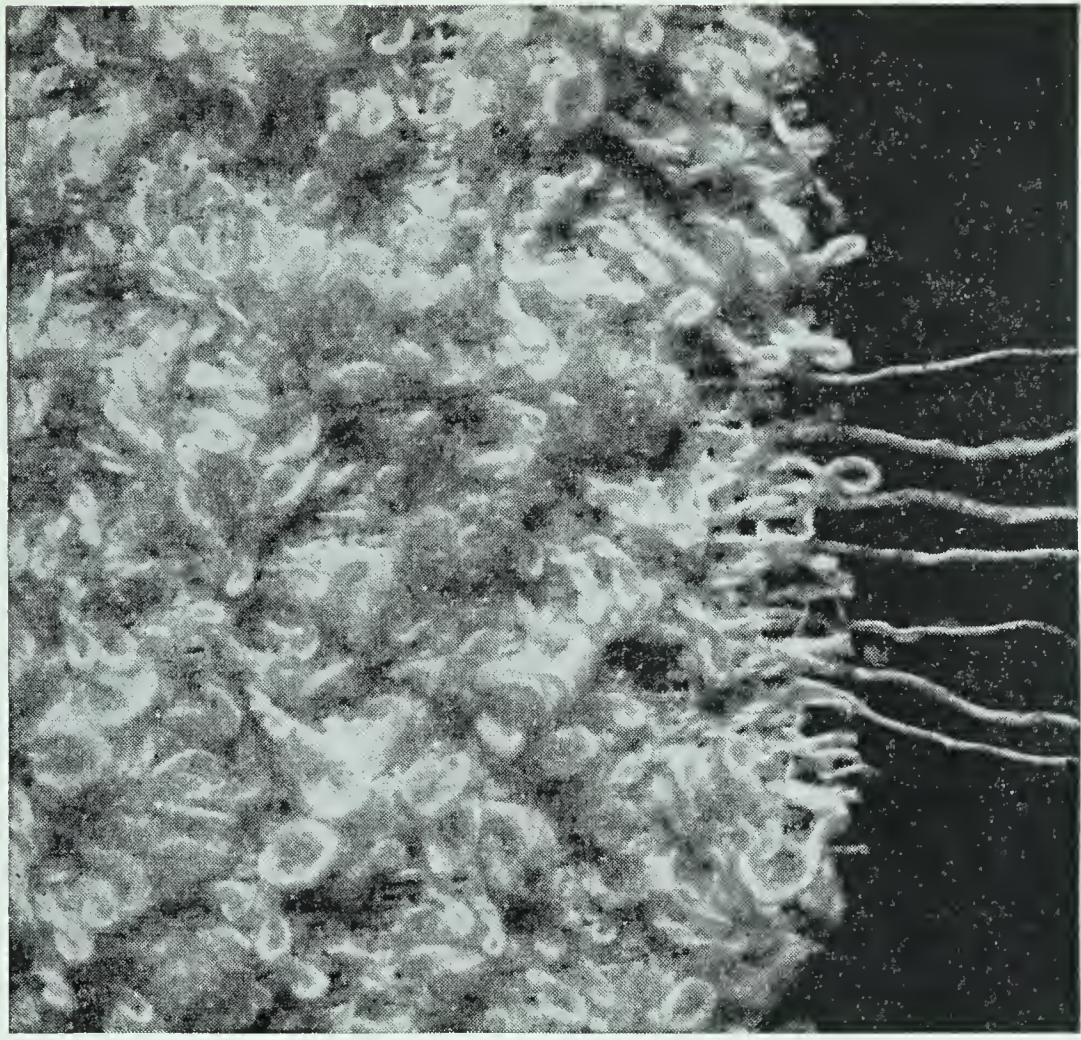
In all cloth the type and quality of fibers, the kind of yarn, the construction and the finish of the fabric determine its qualities. The mass or amount of cotton used determines to a great extent the amount of water a towel holds; and the looseness of the construction of the yarns and the fabric greatly influences the rapidity with which the water is taken up. On the other hand, durability, or the strength of the fabric, is increased by the tightness of the construction of the yarn and the fabric. We must know then just what construction will include the maximum of both absorption and durability possible in a bath towel.

The number of filling yarns that interlace with the ground warp and the pile warp in the formation of each loop may vary from one to five, or more. In fabrics of the same compactness this interlacing determines the security with which the loops are held in the fabric. It is an accepted standard that less than three filling yarns for each loop (three-pick terry) is not satisfactory, and usually no other construction is found in the market.

The consumers' problem of selection is somewhat simplified by the fact that there are two distinct constructions, known as the double-loop and single-loop terry. (See page 463.) In the double-loop construction two pile warp yarns are used together in making the loops, with one ground warp in the body of the cloth for every row of loops. This means twice as many pile warp on the surface as warp in the body of the fabric. In the single-loop, one pile yarn forms the loop. In this construction there is an equal number of ground warp and pile warp in the cloth. Double-loop construction, where two yarns are used together in the formation of the loop, furnishes twice as much surface area as a towel constructed of the same number of yarns per square inch in which only one yarn forms the loop. However, in two towels of the same weight



Courtesy Agricultural Experiment Station, Kansas State College



Terry woven towels. Left, "double-loop"; right, "single-loop" construction.

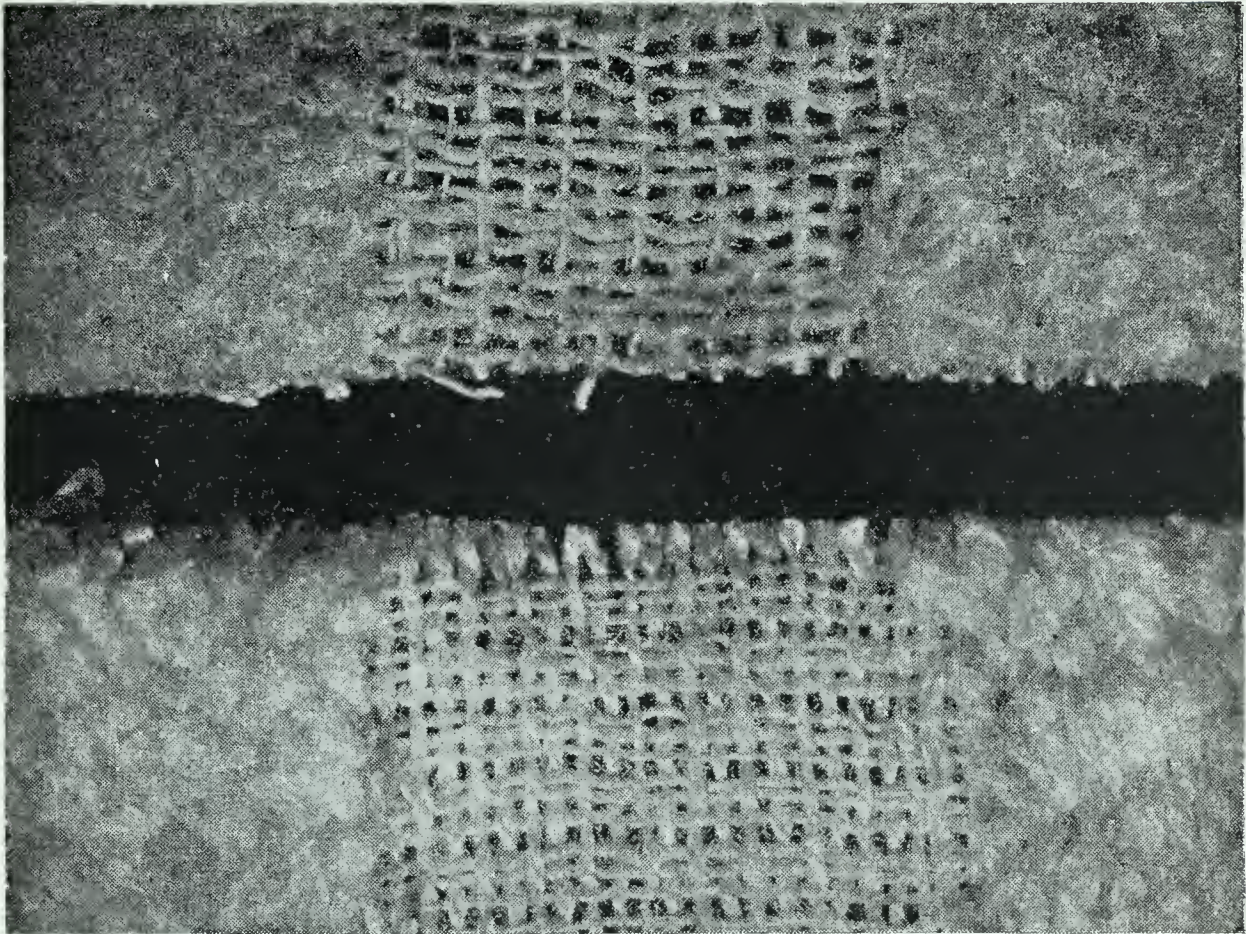
there is a corresponding decrease in the number of ground warp or foundation yarns for the increase in the number of pile warp or loop yarns. This means that with the present methods of construction, a gain in absorption is accompanied by a loss in strength; and this loss is in the warp or lengthwise, which is where the breaks always come in bath towels.

In both the single-loop and double-loop construction there is a variation in the type of yarns used, the number of ends and picks, and the weight, size, and color of the towel. (See page 465.) Ply yarns—yarns made up of more than one strand of fibers—add strength and are sometimes used as ground warp in order to increase the strength of the towel in the direction of strain. A ply yarn is more expensive to construct than a single strand so the use of ply yarns increases the cost of production of the fabric. The use of ply yarns as foundation warp yarns in connection with double-loop construction would compensate, at least in part, for the smaller number of ground warp yarns.

The length of the loops as well as the number of loops on the surface influences the surface area of the fabric. Loops less than one-eighth of an inch in height add little to the absorptive qualities of the towel, and longer loops increase the tendency to catch or snag.

Another point to be considered is that the selvage of towels should be examined to determine its construction. Some cheap towels are woven in double width and cut in two. The one side is finished with a stitching which is none too secure and often breaks, leaving the raw edge to fray. Woven selvages differ in the number of filling yarns that cover the outside warp yarns. To give the best service each filling yarn should come to the outside edge and go around the last warp yarn. (See page 466.) The hems of towels should be straight of the goods with adequate turn-under and securely fastened ends.

The absorbing surface of the towel is lessened in direct proportion to the increase in size and type of border. There is a question whether the actual drying surface is reduced since the ends are generally used only to hold the towel. Fancy col-



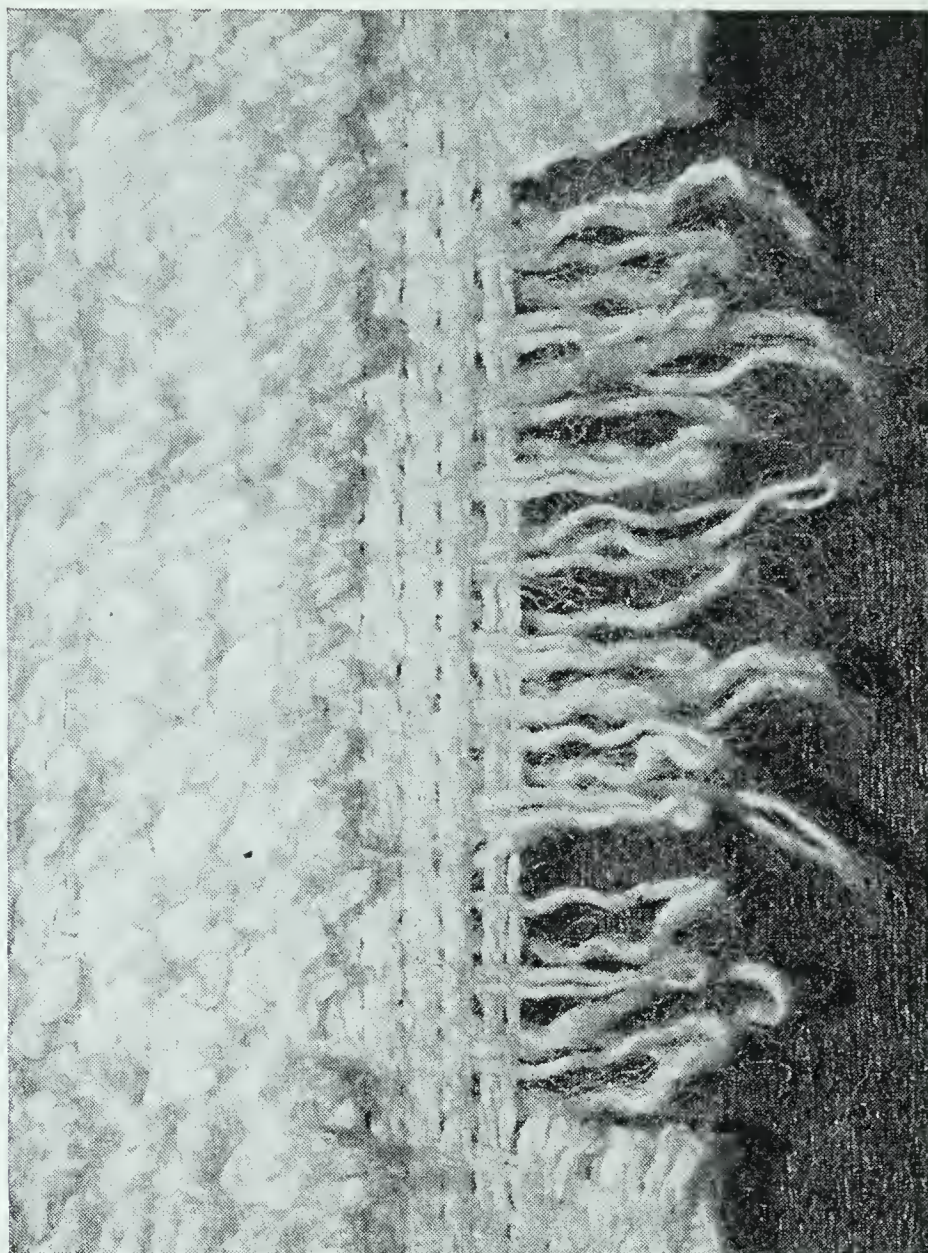
Courtesy Laundryowners National Association of the United States and Canada

It is evident that the upper towel is lacking in strength essential for long wear. The lower towel was 70 per cent stronger than the upper one in the direction of the warp.

ored borders and designs add to the expense of the towel. One must be sure that the colors are fast when choosing colored towels.

One might conclude from the many studies that have been made of bath towels that the following facts will be of assistance in this selection.

Practically all of the towels found on the market are of three-pick terry construction with either single- or double-loop pile. In the single-loop type there is the same number of ground warp and pile warp yarns. Towels with double-loop pile, as a group, excel in absorptive qualities but lack wearing qualities. Ply yarns are usually found only in the ground warp of towels in the higher price range. The cheapest towels are usually double-loop and the most expensive are single-loop construction. A towel should absorb seven or eight times its



Courtesy Laundryowners National Association of the United States and Canada

The selvage of a bath towel must be firm and closely woven to prevent its becoming frayed.

own weight in moisture. Those that absorb only four or five times their weight are considered deficient in this quality.

In a study made at the Kansas Agricultural Experiment Station the durability and absorptive qualities of double-loop and single-loop construction of towels of the same and different prices were compared. Eight types considered representative at that time of low- and medium-priced towels were included in this study. The single-loop towel absorbed more water, but not so rapidly as the double-loop one.

In inexpensive and medium-priced towels the increased ab-

sorptivity of double-loop construction does not compensate for its lack of durability as expressed in terms of breaking strength. Single-loop towels are therefore recommended as a wise selection in this type.

Compactness of background, which is determined by the number of yarns per inch (thread count), as well as the number of filling yarns that hold the loops in place, influences the security of the pile. Reference to the table on page 468 shows that the warp yarns per inch in the ground of the single-loop towels ranged from 25 to 41 and

the warp yarns in the ground of the double-loop towels ranged from 20 to 28. This is evidence that double-loop towels should be examined carefully before purchasing.

These facts, although inadequate, should aid the consumer in determining the comparative qualities of the towels offered for sale and will have to serve until the manufacturers can be persuaded to mark their products with labels furnishing information concerning absorptivity and durability qualities. The consumers' choice, then, would be determined by personal preference as to size, color, and price.

Bath towels with heavy cord borders may draw up in laundering because of the unequal shrinkage of the fabric. A towel of this type is shown in the illustration above.

The following is taken from DDD-T-551a, July 13, 1946:

FEDERAL SPECIFICATION FOR TOWELS: TURKISH

B. Classes and grade.

B—1. The classes shall be as shown in the table on page 469.

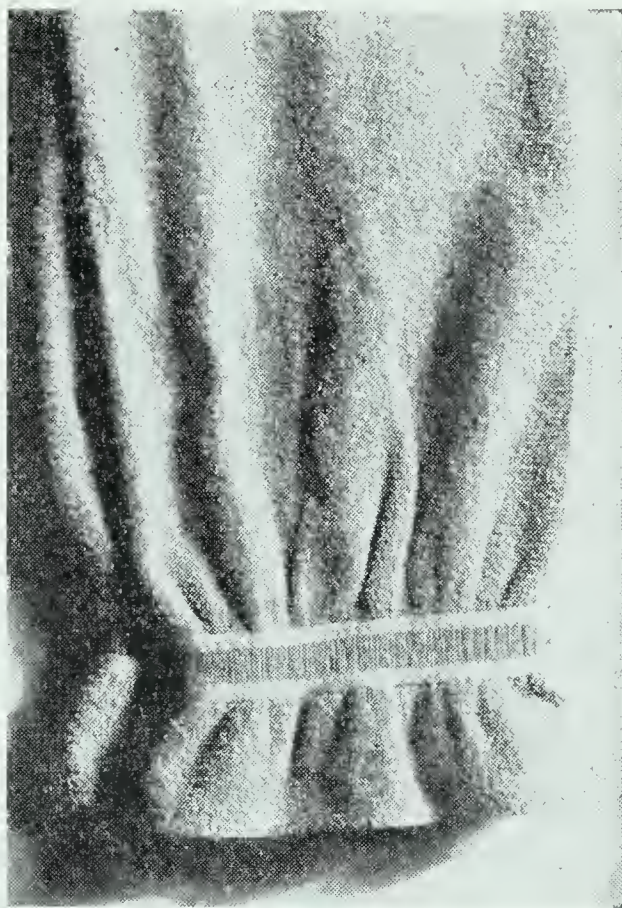


Illustration of effect of a difference in weaving in a turkish towel.

B—2. The grade shall be that known commercially as “firsts.”

C. Material and workmanship.

C—1. *Material*. The towels shall be made of thoroughly cleaned cotton free from waste.

C—2. *Workmanship*. The towels shall be free from avoidable imperfections in manufacture and from defects or blemishes which may affect their appearance or serviceability.

D. General Requirements.

D—1. *Finish*. The towels shall be fully bleached and free from sizing.

D—2. *Weave*. The fabric shall consist of warp and filling ground yarns and warp pile yarns. The fabric shall be woven with a terry weave except that there shall be a border of plain cloth (without the pile) approximately 2 inches wide at each end of the towels. They shall be woven with tightly woven fast selvages, approximately $\frac{1}{4}$ inch wide or with one woven selvage and the other side hemmed. The hem shall be not less than $\frac{1}{4}$ inch wide and shall have not less than 10 stitches per inch.

D—3. *Hemming*. The ends of the towels shall have $\frac{1}{4}$ to $\frac{3}{4}$ inch hems with no raw edges. The corners of the hems shall be backstitched at least $\frac{1}{2}$ inch.

D—4. *Tolerances*.

D—4a. *Number of yarns per inch*. A minimum tolerance of two yarns per inch and any plus tolerance will be permitted.

D—4b. *Width*. A tolerance of plus or minus 1 inch in the length and $\frac{1}{2}$ inch in the width will be permitted.

D—4c. *Weight*. A minus tolerance of $2\frac{1}{2}$ per cent, and any plus tolerance on the basis of 12 towels, will be permitted.

D—5. *Woven name*. When specified the words “United States Government” or other words shall be woven through the center of the towel. The color of the woven name shall have good fastness to laundering, as evaluated in Federal Specification CCC-T-191 of the issue in effect on date of invitation for bids.

E. Detail requirements.

E—1. The construction, weight, size, and breaking strength shall be as shown in table on page 470.

E—2. *Yarns*.

E—2a. *Class A*. The ground and pile warps shall be either 2-ply or single ply yarn of equivalent size; the filling shall be single ply yarn.

FABRIC ANALYSIS OF THE EIGHT TERRY FABRICS USED IN TESTS OF ABSORPTION ¹

TOWEL	YARN IN LOOP	PRICE	SELVAGE	SIZE IN INCHES		WEIGHT IN GRAMS			THREAD PER INCH		
				As Purchased	Laundered	As Purchased	Laundered	Per Sq. In.	Warp	Filling	Pile
I	single	\$0.25	woven	22.25 x 41.00	22.25 x 39.25	190.2	190.1	0.21	36	33	36
II	single	0.25	woven	21.75 x 43.00	21.25 x 40.25	193.2	195.3	0.24	30	29	30
III	single	0.59	woven	22.25 x 42.25	21.12 x 40.50	229.1	232.3	0.27	41	49	41
IV	single	0.15	woven	19.50 x 39.00	19.25 x 39.25	123.8	124.5	0.17	25	29	25
V	double	0.25	woven	21.50 x 43.25	21.75 x 41.12	152.4	151.7	0.18	21	26	42
VI	double	0.15	cut	19.50 x 40.75	17.50 x 36.12	125.4	125.9	0.19	26	30	51
VII	double	0.25	woven	22.00 x 43.50	22.00 x 41.25	178.3	179.5	0.19	20	27	40
VIII	double	0.59	woven	21.50 x 43.00	21.50 x 41.50	241.9	243.6	0.27	28	39	56

TOWEL	PLY OF YARNS			TWIST PER INCH			LOOPS		TENSILE STRENGTH IN POUNDS			STRETCH IN INCHES		
	Warp	Filling	Pile	Warp	Filling	Pile	No. per Sq. In. on Both Surfaces	Length in Inches	Warp	Filling	Pile	Warp	Filling	Pile
I	single	single	single	17	16	11	376	0.23	39.8	33.6	16.4	.52	.53	.99
II	single	single	single	15	11	18	294	0.28	27.0	45.4	17.9	.29	.55	1.08
III	double	single	single	15	13	18	626	0.21	48.2	52.0	15.5	.55	.40	.68
IV	single	single	single	14	11	13	241	0.27	21.8	43.3	11.2	.31	.52	.59
V	single	single	single	15	13	20	380	0.23	17.5	36.7	14.8	.27	.53	.78
VI	single	single	single	17	16	17	504	0.23	19.7	28.8	17.6	.28	.37	.74
VII	single	single	single	15	12	17	374	0.24	18.3	40.2	19.7	.28	.50	.96
VIII	single	single	single	15	14	22	812	0.27	35.2	45.2	19.5	.32	.45	.93

¹ Fern Marie Oline, *Absorptivity of Certain Textile Fabrics*. Unpublished thesis, Kansas State College, 1937.

CLASS	COUNT—NUMBER OF YARN PER INCH		WEIGHT PER DOZEN	DIMENSIONS (FINISHED)		BREAKING STRENGTH GRAB METHOD (MINIMUM)	
	Warp ground and pile	Filling		Width	Length	Warp	Filling
A-1	68	32	<i>Pounds</i> 5.5	<i>Inches</i> 20	<i>Inches</i> 40	<i>Pounds</i> 40	<i>Pounds</i> 35
A-2	68	32	3.0	17	26	40	35

E—2b. *Class B.* The ground warp shall be either 2-ply or single ply yarn of equivalent size; the pile warp shall be single ply yarn with two ends woven as one; the filling shall be single ply yarn.

E—2c. *Class C.* The ground warp shall be either 2-ply or single ply yarn equivalent size; the pile warp shall be single ply yarn with two ends woven as one; the filling shall be either 2-ply or single ply yarn of equivalent size.

Kitchen towels consist of hand towels which may be of linen, cotton, or paper, and dish or glass towels. Towels for use in drying dishes and glassware must absorb moisture readily, be easily cleaned, and leave little or no lint. Flour and sugar sacking, lightweight unbleached muslin, and narrow toweling of linen or of cotton or of cotton and rayon all serve this purpose.

Dish cloths made of a high percentage of rayon have proved inferior to cotton cloths because they do not withstand the severe laundering methods usually given such articles. However, cotton and cotton and linen blends in dish towels give longer service than all-linen dish towels used under the same conditions. Kitchen hand towels should be absorbent, readily laundered, and not harsh.

Suggestions for the Laboratory

Compare fabrics of all-linen table damask with those of mercerized cotton and blends of linen and cotton or linen and rayon. Compare fabrics of similar fiber content suitable for hand towels, for dish towels.

PROBLEM 4. WHAT FACTORS SHOULD GOVERN THE SELECTION OF BED LINENS AND BLANKETS?

The selection of bedding and blankets is quite as important as that of table linens. These articles require the expenditure of a comparatively large sum of money and should give satisfactory service for many years. The usual questions asked of the saleswoman are: "Which is the best quality and how much should I buy?" "What size do I need?"

Sheets and pillowcases. Possibly the question of sheets is the most perplexing. What is the purpose of a sheet? What determines whether a sheet is satisfactory or not? A sheet should furnish comfort to the user and protection for the other bedding. Hence, a sheet that is too short is unsatisfactory, no matter what the quality of the fabric. It is generally more convenient to have sheets for a given bed the same length and width. The lower sheet must be long enough to tuck in well at both ends, and the top sheet must tuck in at the bottom and turn down at the top for at least a quarter of a yard over the bedding.

The length of sheets is usually listed in the inches of the torn or cut but unfinished size. Allowance of 2 inches per yard for shrinkage plus the combined width of the two hems must be made. This sum deducted from the length as listed will approximate the length of the sheet after laundering. A sheet 99 inches long will adequately protect both the bedding and the individual. It will be necessary to purchase three yards of sheeting or a ready-made sheet listed 108 inches long in order to have a 99-inch sheet. In a few instances sheets are labeled with the finished length and are guaranteed not to shrink.

The width of sheets and sheeting is listed in inches or quarters of a yard. For a single bed a sheet 108 inches by $7\frac{1}{4}$ (seven quarter) will allow adequate material for tucking in well on all sides of the mattress. A three-quarter bed requires a sheet 108 inches by $8\frac{1}{4}$, and a double bed 108 inches by $9\frac{1}{4}$. Sometimes a wider sheet is desired and in this case it is well to purchase one which is 108 inches by $10\frac{1}{4}$.




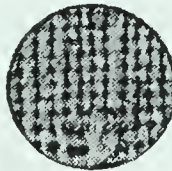







Information as to the size of sheets is always available and is of utmost importance. An inadequate width is unsatisfactory, and an excessive width is wasteful as it has a higher initial cost and the extra weight adds either to the labor or the expense of laundering.

Sheeting is found in both linen and cotton fabrics. The cost of a pair of linen sheets with pillowcases to match is more than most housewives care to spend for these articles. It is a question whether linen sheets furnish as much comfort to the user as those made of cotton, for linen is extremely cold and clammy in cold weather.

Cotton sheeting is of two types, percale and longcloth. Percale sheeting is lighter in weight and finer, having more ends and picks per inch than longcloth. Durability and texture are the important qualities to be considered in the selection of sheets. The texture is important because the sleeper comes into direct contact with the sheet. Sheets must be made of strong fabrics in order to withstand use and laundering. The finer the quality of the fiber and the yarn, the more even the construction and better the finish of the fabric, the more perfect is the texture. Heavier yarns tend to increase the durability and also the weight of sheets. The questions then are: Can fine texture be combined with service qualities at a price within the reach of the average homemaker? How much of one must be sacrificed for the other? What relationship exists between price and these qualities?

Sheets and sheetings are classified as light weight, medium, and heavy muslin, fine count, and percale. These five groups represent not only a difference in weight but progressive quality differences, and also increase in price. In judging price and quality of sheets one must determine the group or classification of sheets, and then make comparisons of qualities within the same group.

The Bureau of Human Nutrition and Home Economics as a result of a study of thirty-nine sheets suggested minimum specifications for these five classes of sheets. (See page 473.) These figures were the result of the analyses of sheets of various brands purchased on the market, and the classification was

FIVE GENERAL TYPES OF SHEETS					
TYPES OF SHEETS	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5
CONSTRUCTION AND WEIGHT	LOW COUNT LIGHT WEIGHT	MEDIUM COUNT MEDIUM WEIGHT	HIGH COUNT HEAVY WEIGHT	FINE COUNT LIGHT WEIGHT	PERCALE – VERY LIGHT WEIGHT
WASHABILITY Microscopic photos showing effect of repeated washings.					
WEAR Determined by relative breaking strength.					
PRICE Relative initial retail price.					
QUALITY Characteristics.	Coarse, loosely woven, heavily filled with starch. Unsatisfactory. Looks good but finish comes out in the wash.	Light or medium muslin. Sometimes mistaken for longer wearing muslin. Not durable enough for real economy.	Firm, strong and even. Durability balanced with soft smooth texture—easy washability. Strongest and longest wearing type.	Finer count—somewhat smoother than heavy muslin—but does not wear so well. Sometimes called "Utility Percale."	Very fine, thin, smooth. . . a luxury sheet for those to whom price is not important. Too costly for general use.

Courtesy Pequot Mills

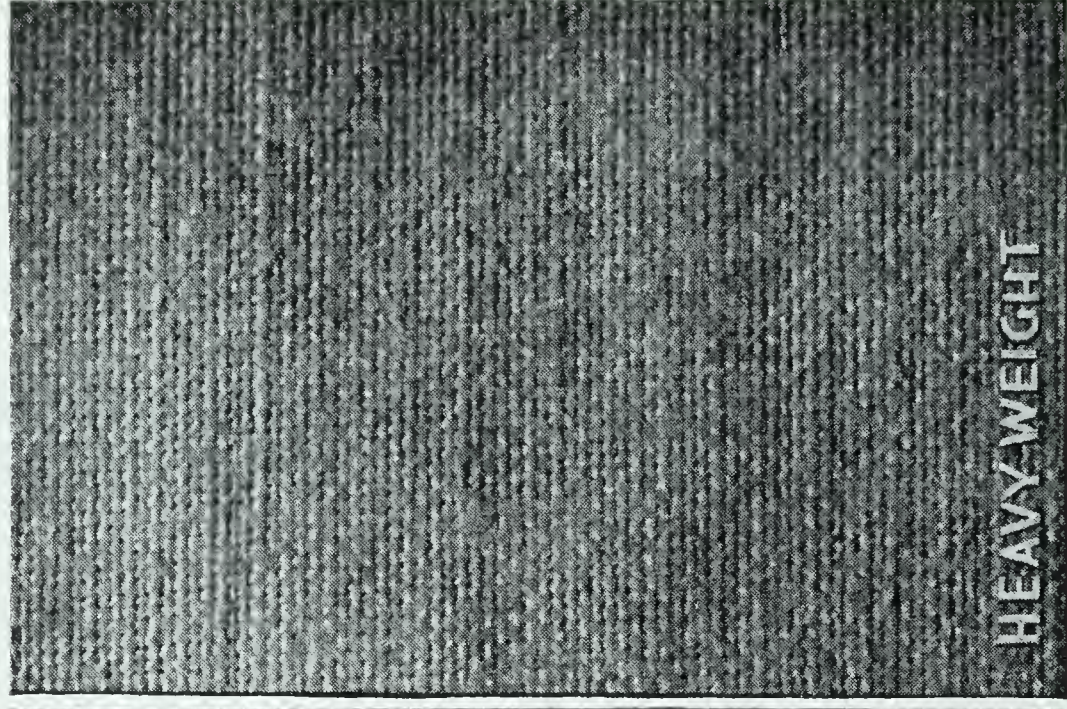
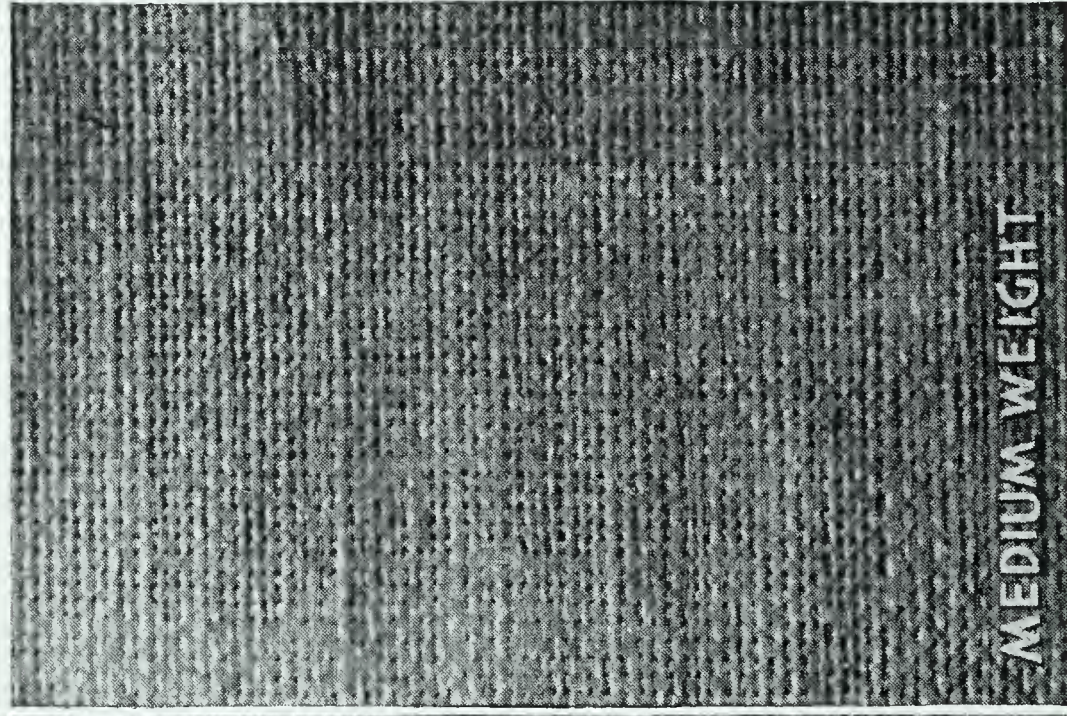
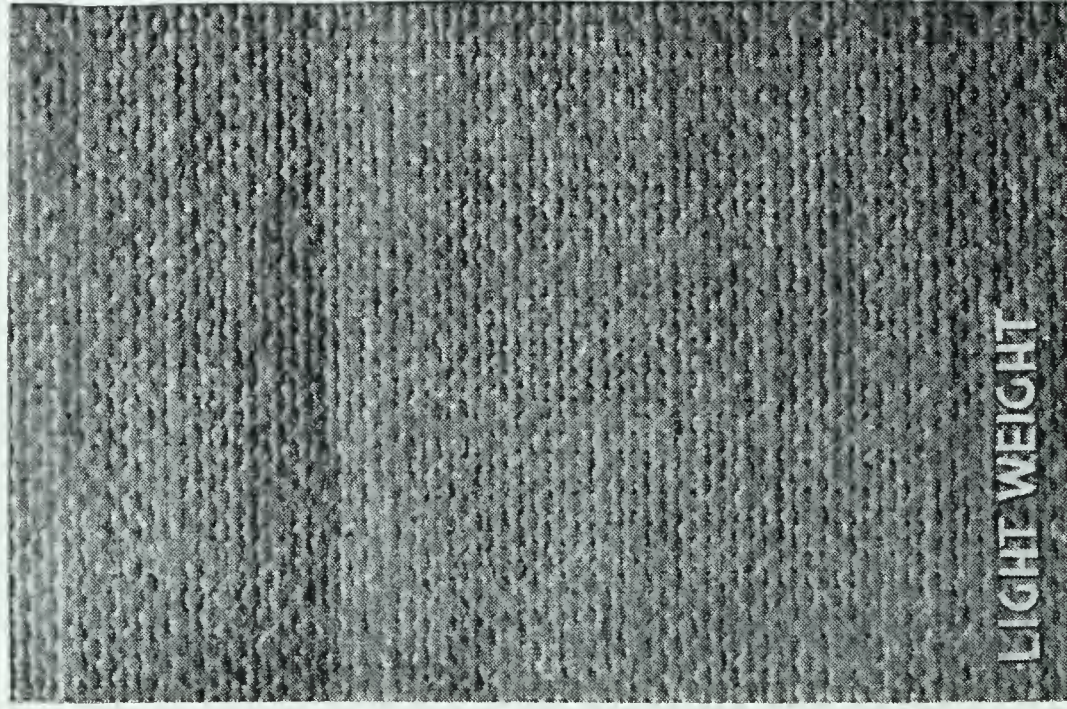
Comparison of five types of sheets.

made on the basis of weight, which is indicated by thread count.

SUGGESTED CLASSIFICATIONS OF SHEETS ¹

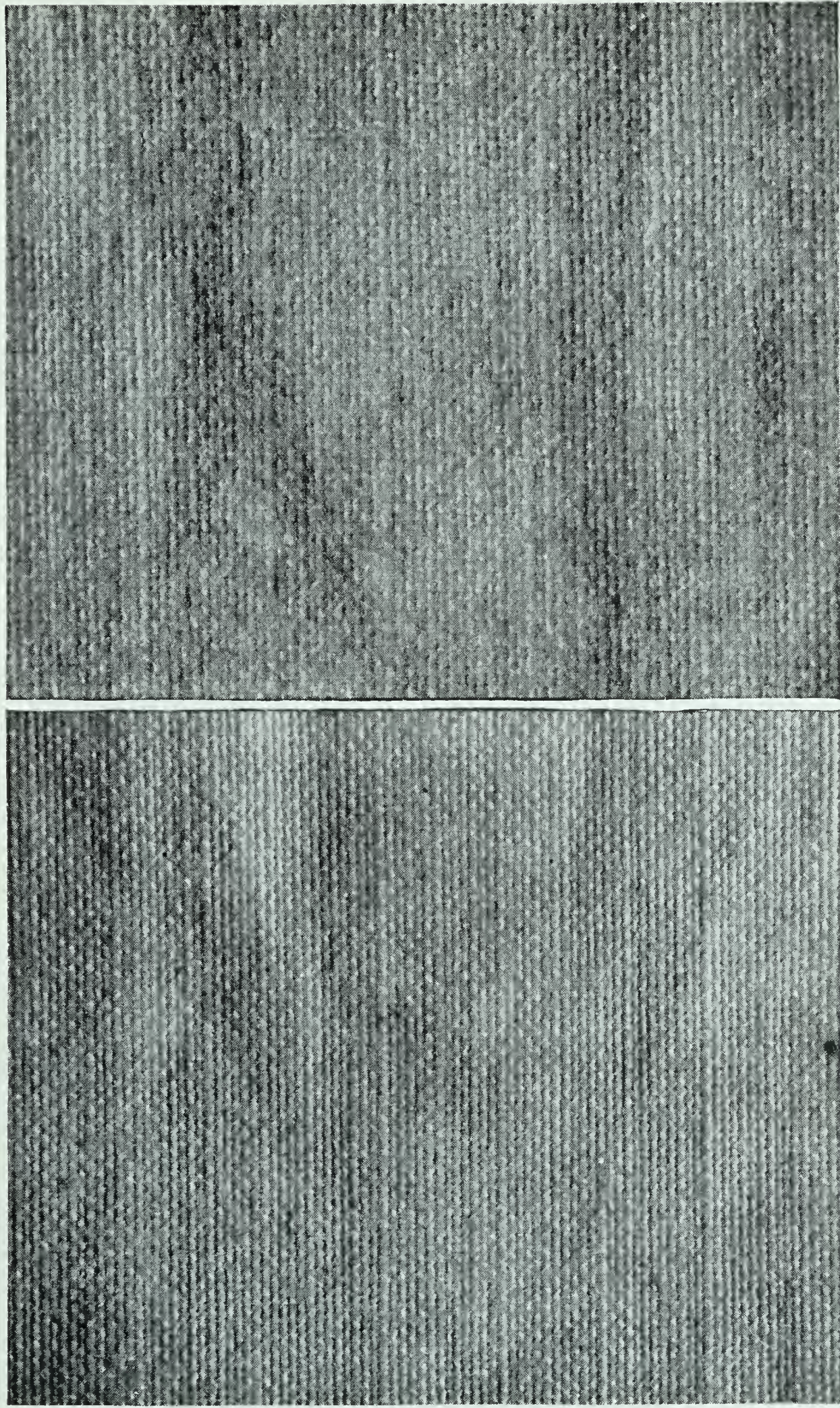
DESCRIPTION OF CLASS	THREAD COUNT	WEIGHT OUNCES PER SQ. YD.	BREAKING STRENGTH IN LBS.
Heavy weight muslin	74 x 66	4.6 minimum	70
Medium weight muslin	70 x 60	4.2 minimum	50
Light weight muslin	60 x 52	3.7 minimum	40
Fine count	86 x 82	3.7 to 4.0	60
Original percale	200 (warp plus filling)	3.8 maximum	60

¹ Ruth O'Brien and Margaret B. Hays, *Sheets Again*, Journal of Home Economics, January, 1937, pp. 11-15.



Courtesy Agricultural Experiment Station, Kansas State College

Muslin sheets showing variation in compactness of the three types. Note the difference in the size of the yarns as well as the number of yarns per inch.



Courtesy Agricultural Experiment Station, Kansas State College

Left, sheets classified on page 473 as fine count, sold as percale. Right, finest texture of sheet, classified as "original" percale.

The minimum requirements for sheets set up by O.P.A. classifies them as to type based on thread count per square inch.

MINIMUM STANDARDS FOR 4 TYPES OF SHEETS, PILLOWCASES, AND SHEETING

TYPE	THREADS PER SQ. IN. ¹	OUNCES PER SQ. YD.	BREAKING STRENGTH ²	MAXIMUM SIZING
180.....	180	3.6	60	4%
140.....	140	4.6	70	4%
128.....	128	4.0	55	6%
112.....	112	3.7	45	10%

On all types: Selvages must be tape. Plain hems on sheets should total 4 inches; on cases, 3 inches. Stitching should be 14 stitches per inch.

¹ This is the total number of threads lengthwise and crosswise; it is best when the number is equal in each direction.

² This must be equal lengthwise and crosswise.

The above classification permits much more sizing than was being used in the better quality sheets and no mention is made concerning shrinkage, which is an important service quality.

Many comparatively large yarns result in a heavy fabric of coarse texture which may or may not have a high breaking strength. Fine yarns packed closely in a fabric result in a lighterweight fabric of fine texture. This fabric also may vary greatly in breaking strength, depending upon the quality and evenness of the yarns and the fibers of which they are made. Many retail stores handle the three classes of muslin sheets and sheeting, bleached and unbleached sheeting in two or more brands, and one or more types of finer quality sheets. These finer quality sheets fall into the class of fine count with regard to thread count and weight, but are often sold as percale. Sheets of as high count as 200 yarns per square inch are not carried by the average retail store.

Heavyweight muslins type 140 of good quality, as the name implies, are strong, heavy fabrics and will give the longest service of any type. Variations within this class are difficult to determine unless the breaking strength and sizing can be obtained. (See page 474.) These sheets are the most expensive of

the muslins. An average prewar price per yard of sheeting of this class in a width for a double bed ($9/4$) was 45 to 55 cents.

Medium-weight muslin type 128 is a finer, lighterweight fabric, second in price and in wearing qualities. Many institutions purchase this quality because of the smaller initial cost and lower cost of upkeep. This weight may be preferred because it is less difficult to handle if laundered at home and is less expensive if the laundry is paid for by the pound. The texture is the best of the muslin groups. (See page 474.) The average price per yard of bleached sheeting of this type was 29 to 45 cents.

Light-weight muslins are comparatively loosely woven, excessive sizing often being added to give the appearance of a better fabric. This class of fabrics is low in thread count and breaking strength, which indicates short service. The yarns are not fine but few in number and comparatively uneven in size, resulting in a sheet of poor texture. (See page 474.) The average price per yard of a $9/4$ sheeting of this class was 27 to 43 cents.

Fine count and percale sheets are sometimes placed in the luxury class not to be purchased by the average homemaker who must consider original cost, upkeep, and service. The breaking strength of these fabrics would indicate longer service than the medium-weight muslins, and their texture is much superior to that of any of the muslins. Reported studies on cost of laundering show a saving that makes a combined initial cost and laundering of heavy muslins (through a period of four years) equal to that of percales. If cost of laundering is considered before making a decision, it may be found that one can afford the luxury of the more perfect texture of fine count or even "original" percale sheets. (See page 475.)

The customary method of hemming is to have a 3-inch hem at the top and a 1-inch hem at the bottom, but a 4-inch hem is sometimes placed at the top and a 2-inch hem at the bottom. Some manufacturers are using 3-inch hems at both ends. This results in sometimes one end and sometimes the other being used for the top, and thus prevents excessive wear in the same part of the sheet. Research studies have proved that the great-

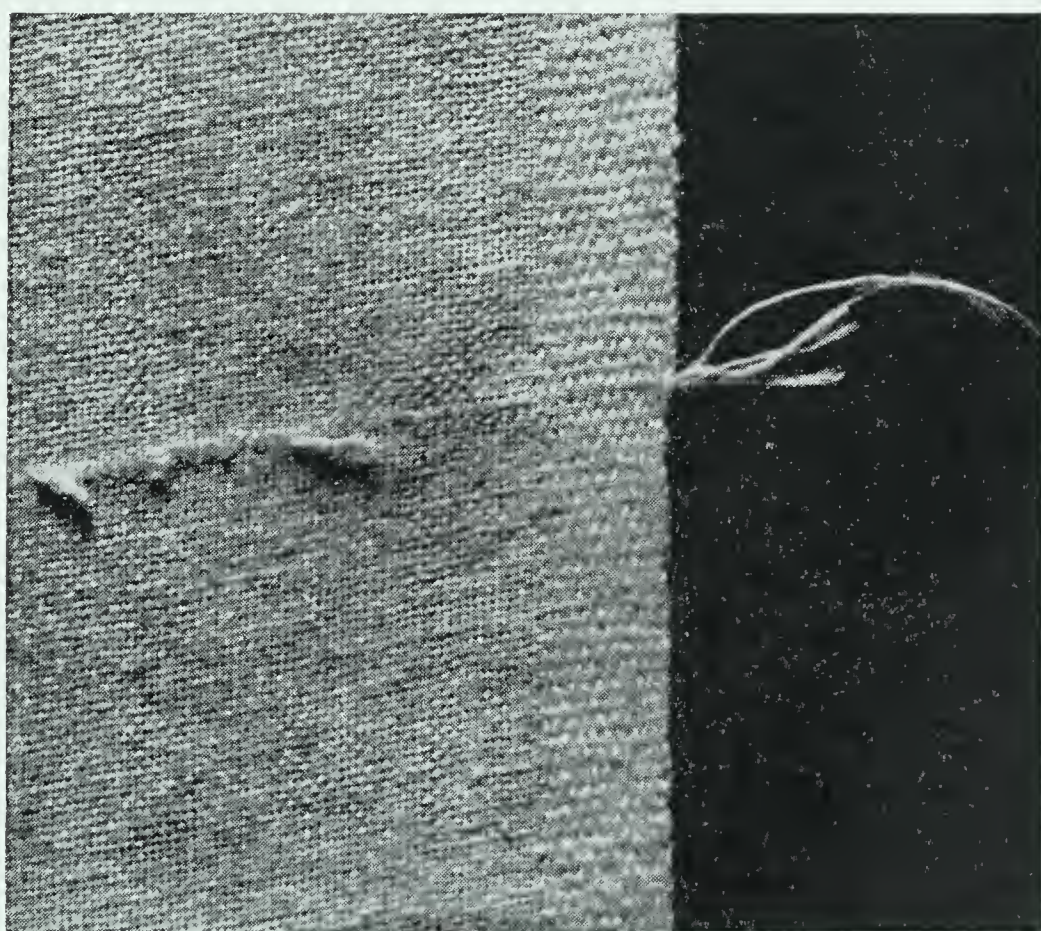
est wear occurs where the shoulders come in contact with the sheet, and not where the sheet is folded.

If economy is of prime importance in the purchasing of sheets, one should be thoroughly acquainted with the comparative prices of sheeting by the yard and of the finished article of the same quality. In some instances the finished sheets cost no more and even less than sufficient material to make the same size sheets. Sheets are often for sale at reduced prices or as bargains. Caution should be used when purchasing such articles. In figuring bargains one must consider not only quality but also the width and length of the sheet. Some merchants are willing to admit that much of their bargain sale material is not from their regular stock but slightly different in quality or size.

A good quality known as "firsts" of any sheeting would be one of even quality throughout without thick and thin places or heavy or broken yarns. It should have a firm, compact selvage, should be finished with a minimum of sizing and in a good, clear white. The hems should be straight of the goods with an even stitching of an average of twelve to fourteen stitches per inch. "Seconds" may be slightly irregular in weave, having heavier and lighter yarns throughout the fabric. (See page 479.) It is doubtful if goods of inferior quality are bargains.

The question of the comparative economy and quality of bleached and unbleached sheeting of the same brand has been answered by studies made at various institutions. A study at the Kansas Agricultural Experiment Station included a comparison of light weight, medium and heavy unbleached and bleached sheeting of the same brands analyzed before laundering, after laundering, and again after twenty launderings. Portions of the unbleached materials were bleached by different methods during the twenty launderings and then compared with the bleached sheeting of the same brand.

Before laundering, the breaking strength of the warp of four of the bleached muslins exceeded that of the unbleached fabrics of the same brand. In every case the strength of the filling of the unbleached fabric was equal to or greater than



Courtesy Agricultural Experiment Station, Kansas State College

Flaws often found in sheets.

that of the bleached fabric of the same brand. After twenty launderings, in every case the strength of both warp and filling of the unbleached fabrics equaled or exceeded that of the bleached fabric of the same brand. These results indicate that unbleached sheeting is superior to bleached sheeting if breaking strength alone is considered.

Nine-quarter bleached sheeting shrank from slightly less than 1.5 inches to 2 inches in width, and from 1.6 to 2.3 inches per yard in length. The excessive shrinkage in the width of the unbleached muslins in some instances equaled practically one-quarter of a yard, a $9/4$ sheet resulting in an $8/4$ width after 20 launderings. For this reason unbleached sheeting should be purchased in wider widths than required in the finished article. The shrinkage in length was so irregular, amounting to 6.88 inches in the extreme cases, that an added allowance should be made when purchasing unbleached material in order to insure adequate length after laundering.

The price of $9/4$ unbleached sheeting is the same or within one or two cents of the price of $8/4$ bleached sheeting, so there would be practically no difference in the price of unbleached and bleached sheeting if an allowance were made of one-quarter of a yard in width for shrinkage of the unbleached.

The texture of the unbleached sheetings after twenty launderings and laboratory bleaching did not equal that of the bleached sheeting of the same brand. After laundering twenty times and storing for one year, the bleached sheetings remained a clearer white than any of the unbleached sheetings that had been laundered twenty times by the different laboratory methods. For these reasons it is questionable whether the added strength of unbleached sheeting compensates for its inferior texture and finish.

A few manufacturers of sheets and sheetings place informative labels on their products. If this information includes breaking strength, number of yarns per inch, percentage of shrinkage, percentage of sizing and weight, it is of great assistance to the purchaser. These items are included in the analy-

sis of sheets which forms the basis of comparative studies of all kinds.

That the more reliable manufacturers are willing and ready to place specifications for their goods on the labels has been proved by a comparison of the qualities of various brands of sheets and of the uniformity of quality within brands. For the first part of this work, lengths of sheeting representing nine different brands were purchased at intervals during the year. At least a month elapsed between any two purchases of the same brand at any one store. This length of time was considered sufficiently long to prevent the purchase of two lengths of fabric from the same bolt. Specifications for one brand tested were available to the consumer.

The breaking strength of different pieces of some of the brands purchased at any one store or at different stores through the nine months' period varied greatly. The greatest variation within one brand was nineteen pounds. The least fluctuation, about one pound, occurred in the brand for which specifications were available.

The amount of soluble sizing in the heavy-weight muslins was small and varied little in the several lengths purchased at different times. A comparison of muslins of different weights showed that as the weight of the fabric decreased, the percentage of soluble sizing increased. This variation was most in different lots of the same brand for the light-weight fabrics. A comparison of the same brands through a period of years indicated similar variations. Brands that rated first one year with regard to breaking strength or the percentage of sizing might be second at another time that tests were made. Again it was found that the brand for which specifications were available remained most constant with regard to qualities.

The results of these studies tend to prove that purchasing sheets by brands would not insure the same length of service even if they were bought at the same store within a period of nine months. However, the fact that the brands for which specifications were available varied the least would indicate that the wise shopper will select brands carrying adequate in-

formation on their labels or at least those for which information is available.

If sheets bearing adequate informative labels are not available, it is probably wiser to select familiar brands with which one has had some experience rather than unfamiliar brands for which no information can be obtained.

The use of specifications similar to those set up by the government for purchasing of sheets would take the guesswork out of selection. Such specifications are found on a few brands of sheets, now available on the market. Some of these follow the government master specifications a part of which is given below.

The following is from CCC-S-271a, May 26, 1945.

FEDERAL SPECIFICATION FOR SHEETING: COTTON, BLEACHED, WIDE

B. Classes.

B—1. The sheeting shall be of the following classes, as specified in the invitation for bids:

Class A— 4.6 ounces per square yard (74 x 66)

Class B— 4.0 ounces per square yard (68 x 60)

C. Material and Workmanship.

C—1. *Material.* The material shall be made of thoroughly cleaned cotton free from waste.

C—2. *Workmanship.* The material shall be free from avoidable imperfections in manufacture and from defects or blemishes affecting the appearance or serviceability.

D. General Requirements.

D—1. *Weave.* The weave shall be plain.

D—2. Single cuts shall be between 40 and 80 yards in length and double cuts between 80 and 120 yards.

D—3. *Width.* The width shall be 42, 54, 63, 72, 81, and 90 inches, as specified. A minus tolerance of $\frac{1}{2}$ inch and any plus tolerance are permitted.

E. Detail Requirements.

E—1. The thread count, weight, and breaking strength shall conform to those given in the first table on page 483:

Pillowcases. Pillowcases are usually made of the same material as sheets. They may be purchased ready made, or may be made at home from pillow tubing or flat material. If flat

CLASS	COM-MERCIAL DESIG- NATION	WEIGHT (MINI- MUM)	COUNT-NUMBER OF YARNS PER INCH (MINIMUM)		BREAKING STRENGTH (MINIMUM) GRAB METHOD	
			WARP	FILLING	WARP	FILLING
		<i>Ozs. per sq. yd.</i>			<i>Pounds</i>	<i>Pounds</i>
A.....	140	4.6	74	66	70	70
B.....	128	4.0	68	60	55	55

COMMERCIAL SPECIFICATIONS OF TWO BRANDS OF SHEETS COMPARED
WITH GOVERNMENT SPECIFICATIONS
(In Per Cent)

	U. S. GOVERNMENT SPECIFICATIONS	COMMERCIAL SPECIFICATIONS No. I	COMMERCIAL SPECIFICATIONS No. II
Thread count (per sq. in.)			
Warp.....	74	75.8	72
Filling.....	66	67.4	72
Tensile strength (in pounds)			
Warp.....	70	85	71
Filling.....	70	77.6	72
Weight (oz. per sq. yd.).....	4.6	5.02	4.7
Sizing.....	...	Less than 1%	.75%

material is used, the length of the pillowcase must follow the warp yarns. All ready-made pillowcases are thirty-six inches long, but vary in width. The width should be chosen according to the pillows, allowing about one inch on each half width.

FEDERAL SPECIFICATION FOR PILLOWCASES: COTTON, BLEACHED

B. Types and Grades.

B—1. The pillowcases shall be furnished in the types specified in the table on page 484:

C. Material and Workmanship.

C—1. *Material.* The material shall be made of thoroughly cleansed cotton free from waste.

C—2. *Workmanship.* It shall be free from avoidable imperfections of manufacture and from defects or blemishes affecting the appearance or serviceability.

SIZES OF PILLOWCASES

	WIDTH	LENGTH (TORN)
	<i>Inches</i>	<i>Inches</i>
Type I.....	38	26
Type II.....	38	32
Type III.....	42	26
Type IV.....	42	31
Type V.....	42	34
Type VI.....	42	36½
Type VII.....	45	26
Type VIII.....	45	34
Type IX.....	45	36½
Type X.....	45	38½

D. General Requirements.

D—1. *Weave.* The weave shall be plain.

E. Detail Requirements.

E—1. *Thread count.* The minimum threads per inch shall be 74 in the warp and 66 in the filling.

E—2. *Weight.* The minimum weight per square yard shall be 4.6 ounces.

E—3. *Breaking strength.* The minimum breaking strength (grab method) shall be 70 pounds in the warp and 70 pounds in the filling. The average of 5 breaks shall apply.

E—4. *Hems.* The pillowcases shall have a one inch (approximate) hem at the open end, except for Type I which shall have a three-quarter inch (approximate) hem.

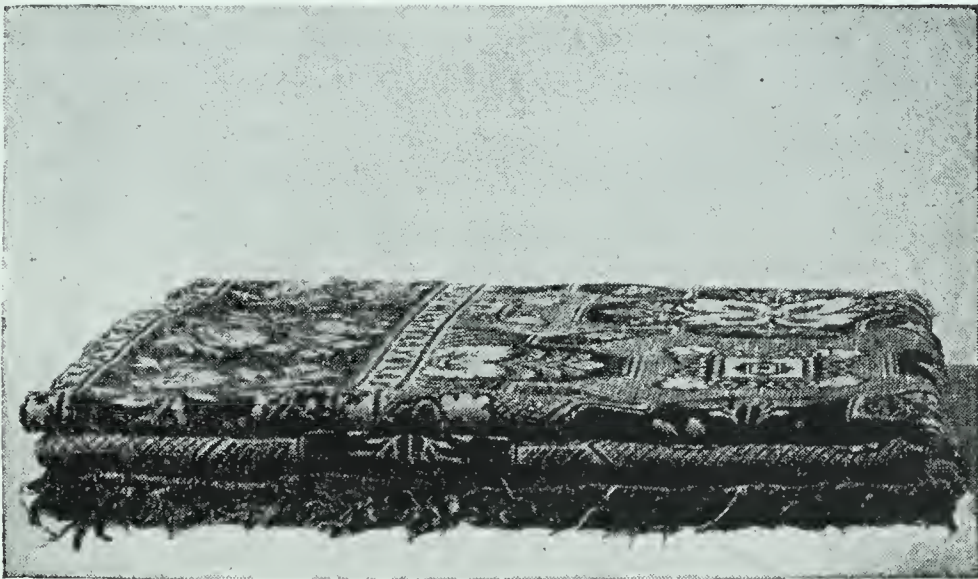
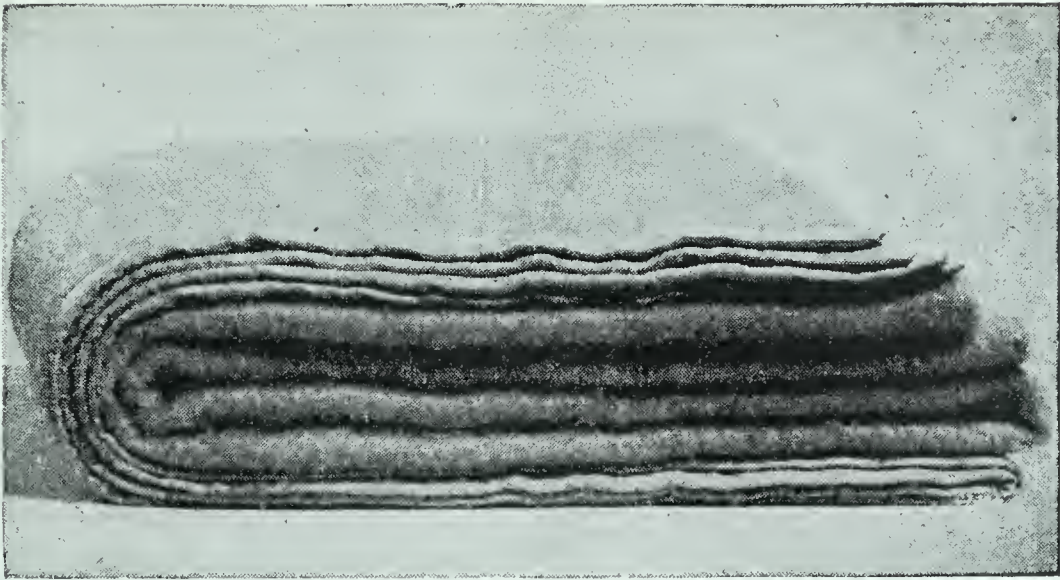
E—5. *Seams.* Where the seams form a union of edges, a type of seam and stitch shall be used which will prevent raveling of the goods.

E—6. *Stitches.* The stitches in the hems and seams shall not be less than 14 to the inch and shall be machine stitches.

E—7. *Finish.* The pillowcases shall be fully and properly bleached.

Blankets. What is required of other bedding than sheeting? Warmth is primarily the reason for the use of other bedding. This need is commonly met by the use of blankets.

Blankets were once required to serve not only as bedding but also as curtains, carpets, and wrappings about valued

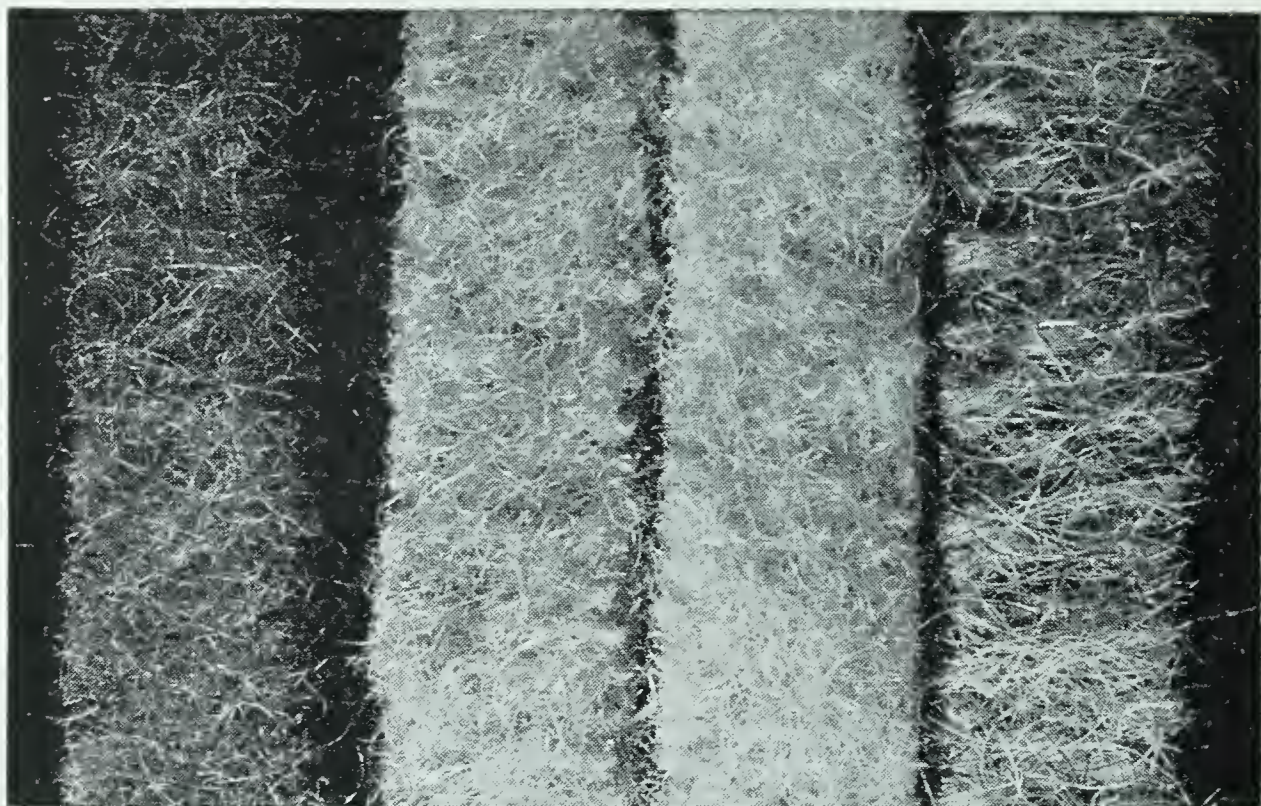


Courtesy Agricultural Experiment Station, Kansas State College

Top, wool blanket—beautiful in color and texture; also, light and warm. Bottom, colonial wool coverlet—artistic and durable, but heavy and lacking in warmth.

goods. In such case they were often stiff and hard, being waterproof and wind resistant at the sacrifice of their ability to protect against cold.

Today blankets used in our homes are constructed for warmth. At one time fiber composition was believed to be the determining factor in the value of such covering; “all wool” was regarded as the synonym of warmth, and the more wool fiber used per square foot, the greater protection the fabric was supposed to furnish. Today construction and thickness



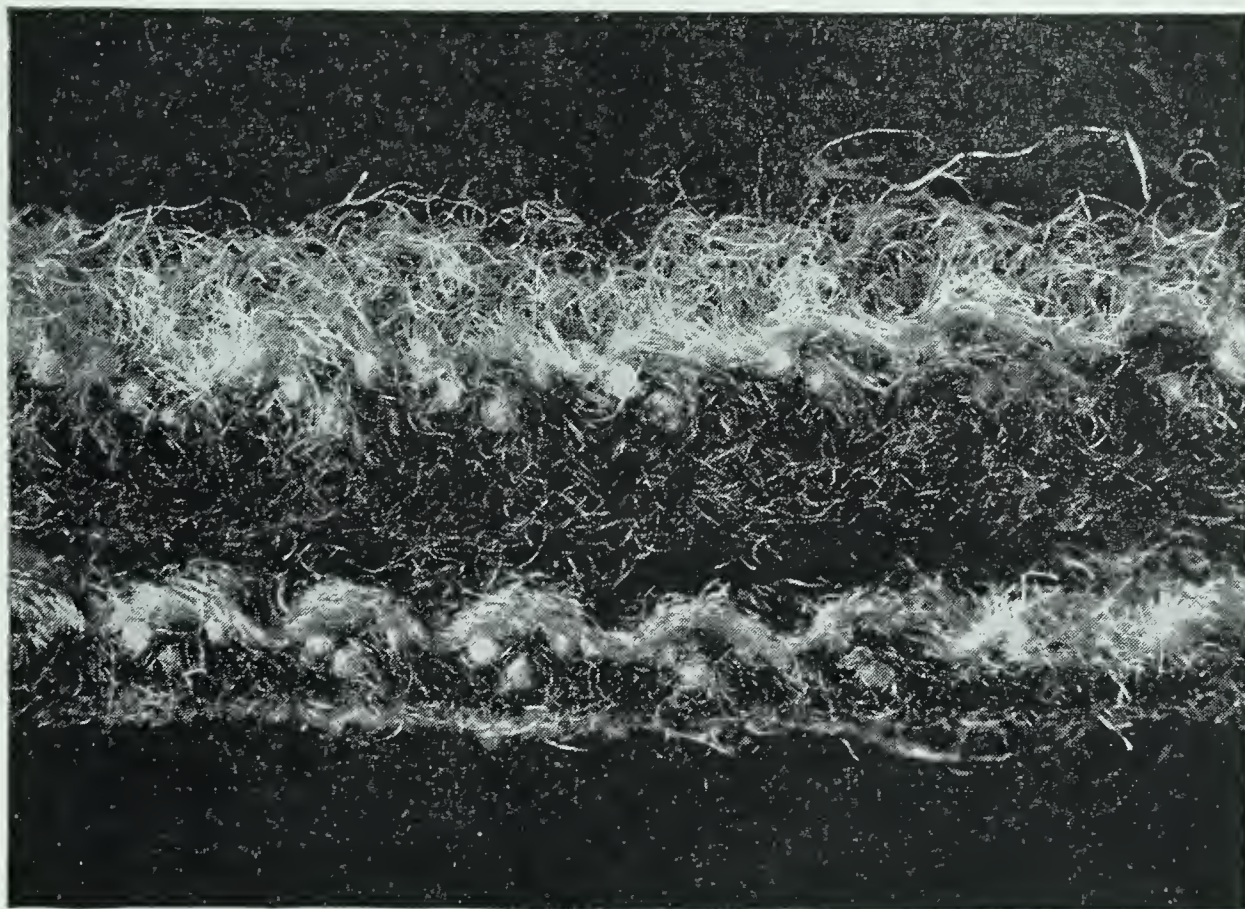
Highly magnified surface view of four blankets, showing difference in kind of fiber and type of nap.

are found to be determining factors of the heat-retaining quality of a blanket. Fabrics with a long, fluffy nap, so constructed that they enmesh a large quantity of air, have been found to possess the low heat transmission desired, regardless of the nature of the fiber. Long wool fibers woven into a blanket of close construction with a long, thick nap will furnish the desired protection, and will retain this property.

Warmth. A study ¹ of ten blankets of different qualities furnished an opportunity to compare the relative warmth and strength of blankets found on the market. The warmth was determined by the protective value—that is, the ability to resist the loss of heat from a body. (See table on page 488.)

The strong blankets were also the warm blankets, and any blankets studied that weighed less than twelve ounces per square yard lacked either warmth or breaking strength. Seemingly a mass or weight of fibers of at least twelve ounces per square yard is required for the construction of a fabric that can be napped sufficiently to prevent excess flow of heat

¹ Unpublished Study, Kansas Agricultural Experiment Station.



Courtesy Agricultural Experiment Station, Kansas State College

Napped and unnapped blanket fabric, showing the effect of napping on the thickness of blankets.

through it and at the same time retain sufficient strength in the filling yarns to withstand wear and cleaning.

A single blanket 60 x 84 inches in size should weigh not less than two and three-fourths pounds. A single blanket 66 x 84 inches should weigh not less than three pounds; and a single blanket, size 72 x 84 inches, suitable for a full-sized bed, should weigh not less than three and one-half pounds.¹

Durability. Blankets must not only protect from cold but must be durable enough to withstand wear and cleaning. The type of fibers used, the construction and the finish of the blanket, all influence its durability. Only long fibers should be made into a well-napped blanket.

Results of laundering tests indicate that a strength of from 35 to 40 pounds in the warp (the lengthwise yarns) and not less than 20 pounds in the filling (the crosswise yarns) is de-

¹ A study made at the Bureau of Home Economics, Washington, D. C., showed that blankets weighing less than twelve ounces per square yard lacked either strength or protective value.

ANALYSES OF CERTAIN BLANKET FABRICS

LABEL		BREAKING STRENGTH				WEIGHT LB. PER 72" x 84"	TOTAL THICKNESS IN MM.	PER CENT ENMESHED AIR	PROTECTIVE RATIO	
		In Pounds		Per Cent Loss					Ratio	Per Cent Increase
		Warp	Filling	Warp	Filling					
All wool										
I *	A	35.5	37.5		81.30	2.94	3.10	94.20	1.24	20.20
	B	30.5	7.0				5.24		1.49	
II *	A	24.4	22.0		70.40	2.43	3.20	95.64	1.25	18.40
	B	25.0	6.5				5.57		1.48	
III *	A	53.0	36.5		39.70	4.41	4.30	93.79	1.33	23.30
	B	54.5	22.0				8.18		1.64	
IV *	A	28.0	74.0		58.10	5.33	5.25	94.42	1.42	18.30
	B	27.5	31.0			2.60	9.79	95.24	1.68	
V *	Blue	22.5	9.0			2.45	3.78	94.84	1.43	
VI *	Rose	21.5	6.0			4.50	5.70	93.98	1.49	
VII *		40.5	5.5			4.20	8.30	92.14	1.59	
VIII		38.0	14.5			2.97	5.08	94.89	1.66	
IX		31.5	11.0			3.14	5.85	95.16	1.59	
X		34.5	19.0				7.44		1.49	
Part wool					Soluble Sizing					
XI		35.0	22.6		3.50	2.47	5.69	96.49	1.43	
All cotton										
XII		30.5	18.5		14.12	2.08	5.73	97.38	1.33	
XIII		36.0	3.5		2.17	2.80	6.01	96.67	1.36	
XIV		40.0	20.5		1.97	3.47	7.14	95.80	1.43	
XV		34.5	11.0		4.99	3.11	5.76	96.26	1.36	
XVI		41.5	14.5		3.43	3.91	6.97	94.12	1.39	

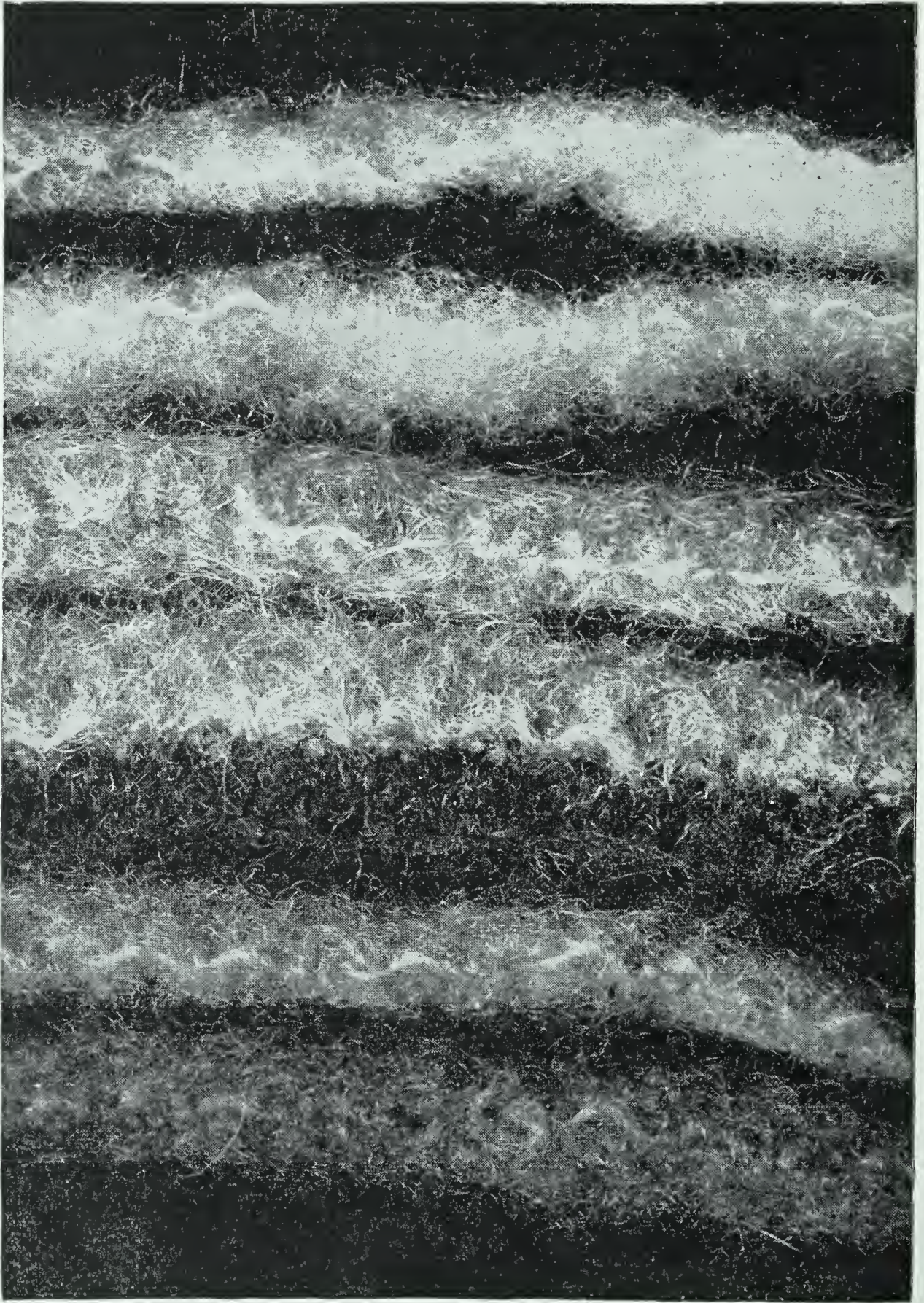
* Materials furnished by manufacturer.
A—Unfinished fabric.
B—The same fabric after finishing.

sirable. This strength is required to withstand the treatment given in power laundries and is necessary also for blankets that are to be laundered at home. Wool absorbs and holds large quantities of water. The fiber is weaker when wet and the yarns in a blanket with less than 20 pounds breaking strength would be most likely to pull apart under their own weight when hung to dry.

It was found in the study of blankets mentioned above that the finishing or napping affected the strength of the warp yarns but slightly, but that from 62 to 81 per cent of the strength of the filling yarn was lost. This was due to excessive napping done in an effort to give warmth and fluffiness to the fabric. The original blanket material possessed more than 20 pounds breaking strength in the filling. The napping of one light-weight fabric reduced the filling strength from 37.5 to 7 pounds, of another from 22 to 6.5 pounds. This represented losses of 81 and 70 per cent, respectively.

Comparison of the weight of the blankets indicated that strength, warmth, and weight go hand in hand. The weight per square yard of four of the finished blankets, with a low breaking strength, was in two cases slightly more than 10 ounces per square yard, and in others much less. A blanket of 10 ounces per square yard would weigh less than 3 pounds in a 72 x 84-inch blanket. Warmer, stronger blankets weighed more than 4 pounds in a 72 x 84-inch size. With the greater weight there was not only more strength, but approximately one-third more warmth. This would indicate that the lessening of the amount of fiber used in blankets and the increase in the degree of napping have been carried too far in some of the blankets found on the market. If an insufficient mass or quantity of fibers is used in the original fabric there will not be sufficient fibers left in the filling yarn to give it the required strength after it is given a high degree of napping.

Recent research carried on at Kansas State College indicated that the thickness of the blanket rather than the fiber content influenced the flow of heat through the blanket. In this study 13 blankets were tested to determine the effect of fiber content and care on resiliency, thickness, and thermal



Courtesy Agricultural Experiment Station, Kansas State College

Edges of blankets, showing difference in thickness. Note weak spots in the two white blankets.

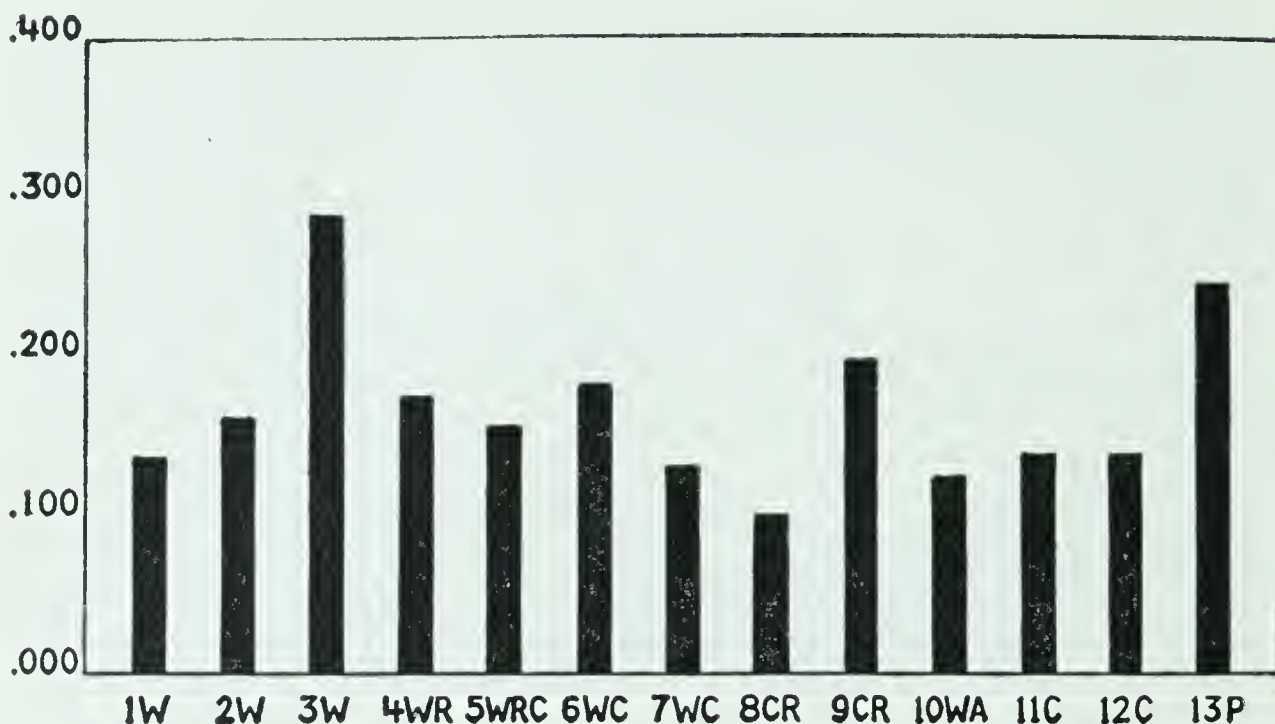
conductivity of blankets.¹ The blankets used included one of Aralac and wool, two of cotton and rayon, one of paper, one of wool and rayon, one of wool, cotton and rayon, as well as three all-wool, two of wool and cotton and two all-cotton. For means of identification each blanket was given a number and a letter or letters indicating fiber content; W for wool; C for cotton; R for rayon; A for Aralac; and P for paper. The price of the three all-wool blankets had to be estimated as they had been furnished by the manufacturer for a previous study. The following table includes the fiber content, price, and size of the blankets.

FIBER CONTENT, PRICE AND SIZE OF BLANKETS USED IN THIS STUDY

NUMBER	FIBER CONTENT	PRICE	SIZE
1 W.....	Wool	\$ 9.00 ¹	62 x 82
2 W.....	Wool	9.00 ¹	63 x 82
3 W.....	Wool	18.00 ¹	75 x 90
4 WR.....	Wool and rayon 15% 85%	5.95	75 x 92
5 WRC.....	Wool, rayon, and cotton 25% 50% 25%	6.95	72½ x 82½
6 WC.....	Wool and cotton 5% 95%	5.00	64 x 82
7 WC.....	Wool and cotton 20% 80%	4.98	64 x 164½
8 CR.....	Cotton and rayon 50% 50%	5.00 ¹	74 x 89
9 CR.....	Cotton and rayon 50% 50%	4.79	70½ x 82
10 WA.....	Wool and aralac 80% 20%	8.50	83 x 74
11 C.....	Cotton	2.98	76 x 89
12 C.....	Cotton	1.79	76 x 90
13 P.....	Paper	1.70	68 x 77½

¹ Estimated price, blankets furnished gratis for a former study.

¹ Hess, Katharine, and Gilmore, Pearl Adell, "The Effect of Fiber Content and Care on Resiliency, Thickness and Thermal Conductivity of Blankets." *Rayon Textile Monthly*, Vol. 26, No. 5 (1946), pp. 78 (252), 82 (256).



A comparison of the thermal conductivity of blankets in their original state on the basis of equal thickness. A short bar indicates a warm blanket.

The all-cotton blanket No. 12 was really a blanket sheet. The paper blanket, although not common, was a type available on the market and of interest in the study.

The table on page 493 shows the thickness of the blankets in their original state and the effect of laundering and dry cleaning on this property. The effect of these treatments on the resiliency of these blankets is also shown in this table. The resiliency of the blanket is important because if a material is resilient it tends to maintain its thickness, which proved to be an important property.

In order to compare the effect of fiber content on the "warmth" of the blankets it was necessary to calculate the flow of heat through an equal thickness of each type of fabric. The flow of heat through the blanket materials calculated on equal thickness is illustrated above. A study of this graph, in which a long bar indicates a large loss of heat, shows the paper material No. 13 to be warmer than No. 3 which was a loosely constructed all-wool material. One must not forget that this is a comparison of only the fiber content and construction on a basis of equal thickness for all fabrics.

RESILIENCY AND THICKNESS OF THIRTEEN SELECTED BLANKETS IN THE ORIGINAL STATE, AFTER FIVE LAUNDERINGS,
FIVE DRY CLEANINGS AND TWO AND ONE-HALF MONTHS OF STORAGE

Blankets	RESILIENCY (PER CENT)				THICKNESS (INCHES)			
	Original State	Laundered 5 Times	Dry Cleaned 5 Times	Stored 2½ Months	Original State	Laundered 5 Times	Dry Cleaned 5 Times	Stored 2½ Months
1 W.....	69.0	66.9	60.0	68.0	.219	.272	.272	.208
2 W.....	61.8	66.5	64.1	74.1	.244	.290	.314	.208
3 W.....	78.0	71.3	62.3		.398	.415	.440	
4 WR.....	62.5	45.9	51.2	54.7	.311	.350	.358	.216
5 WRC.....	63.0	59.7	57.9	64.8	.365	.318	.402	.244
6 WC.....	56.0	29.6	41.5	52.9	.207	.240	.216	.201
7 WC.....	51.8	43.2	45.9	57.1	.242	.232	.236	.149
8 CR.....	58.0	44.2	40.6	49.0	.284	.272	.280	.211
9 CR.....	46.4	50.3	41.1	57.2	.319	.244	.291	.192
10 WA.....	58.5	42.8	57.0	67.8	.209	.276	.271	.236
11 C.....	49.3	30.0	44.2	37.4	.240	.197	.216	.224
12 C.....	40.9	23.3	32.6		.157	.118	.165	
13 P.....	39.4	*	*	46.1	.201	*	*	.138

* The paper blanket could not be cleaned.

The effect of dry cleaning and laundering on the thickness of a fabric has a direct influence on the ability of the blanket to prevent the flow of heat through it.

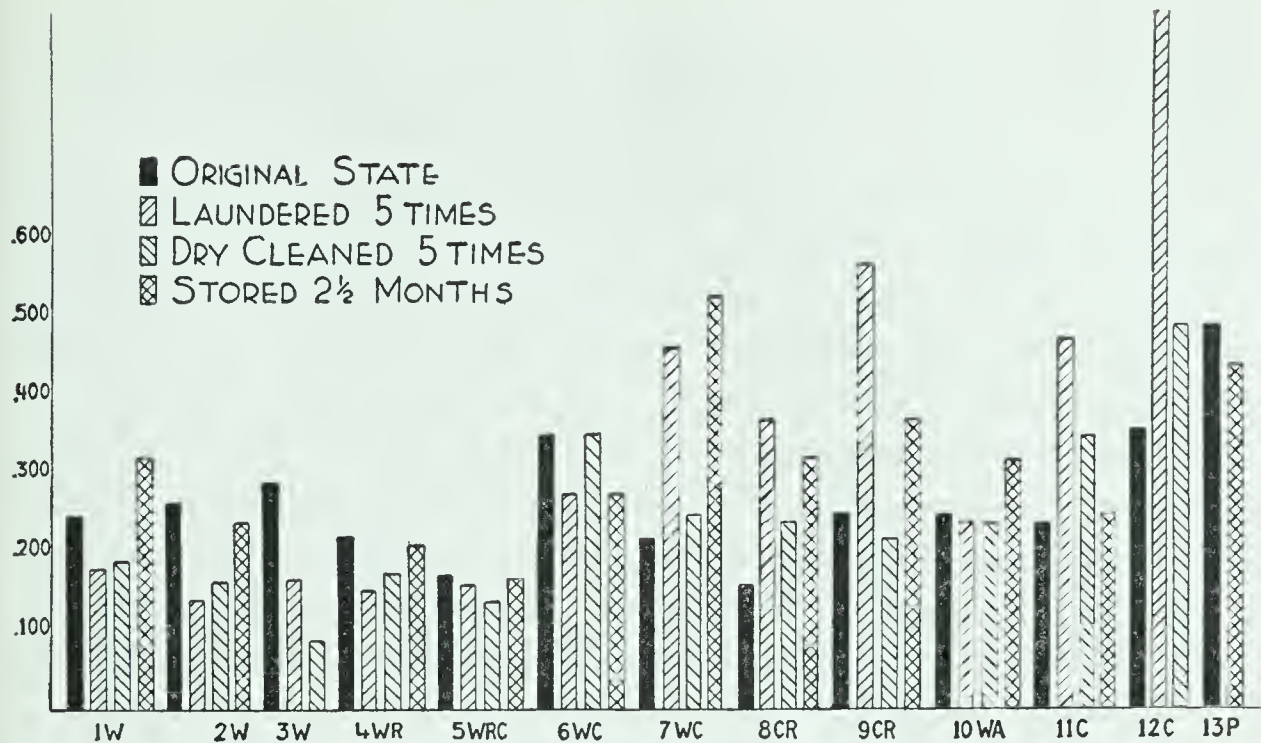
SHRINKAGE OF BLANKETS

BLANKET	LAUNDERED 5 TIMES						DRY CLEANED 5 TIMES	
	PERCENT SHRINKAGE		TENSION REQUIRED TO RESTORE (L.B.)		PERCENT RESTORABILITY		PERCENT SHRINKAGE	
	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
1 W.....	8.0	2.8	4	1.0	2.2	0.8	0.8	0.5
2 W.....	9.7	1.0	4	0.5	0.2	0.2	1.0	1.3
3 W *.....	6.0	2.4					0.4	0.4
4 WR.....	16.0	2.4	4	1.0	3.2	1.0	3.5	1.3
5 WRC.....	13.3	0.7	4	0.5	2.3	1.6	3.8	3.7
6 WC.....	8.6	2.0	4	1.0	3.0	1.2	1.7	1.7
7 WC.....	7.2	0.1	4	1.5	0.2	0.0	3.8	0.1
8 CR.....	8.0	-1.0	4	0.5	-0.2	0.0	1.7	-0.9
9 CR.....	13.7	-2.5	4	0.5	1.8	0.7	3.7	-0.3
10 WA.....	9.4	4.1	4	3.0	4.7	-0.5	0.2	-0.6
11 C.....	8.6	8.9	4	4.0	5.3	0.8	2.2	1.3
12 C.....	7.2	0.9	4	0.5	1.9	0.8	2.3	0.0
13 P **.....								

* Not sufficient material for all tests.
** Could not be cleaned.

Reference to page 495 shows the effect of cleaning on the warmth of the blankets. A study of this plate shows that both dry cleaning and laundering increased the protective value of the three all-wool blankets and all but one blanket containing wool. All blankets of cotton and rayon and the all-cotton blankets lost part of their protective value as the result of five launderings, and five dry cleanings had a similar but slighter effect on all of this group except 9 CR. The paper blanket could not be cleaned and could not be considered durable.

The shrinkage due to five dry cleanings as compared with the shrinkage due to five launderings is given in the table above. The results of these tests showed that all blankets shrank more in laundering than in dry cleaning. Excessive shrinkage resulted from laundering of some of the blankets. The cotton and part cotton blankets in some instances shrank



A comparison of the effect of laundering, dry cleaning, and storage on the conductivity of heat through the blankets. If the bar shortened, warmth increased.

as much or more than the wool ones. Laundering caused greater loss in color than dry cleaning. The comparative restorability of the blankets in percentage is shown in the table on page 494. Blankets that cannot be restored to within two per cent of their original size are not considered satisfactory in this respect. Numbers 4, 8, 10, and 11 could not be drawn back with the application of a four-pound weight.

From this study it may be concluded that it is the thickness and type of construction of a blanket that determines its warmth. If the blanket is to have only occasional use and will not have to be cleaned soon, a blanket of rayon and cotton or all-cotton or even paper would prove satisfactory. However, if one wishes a blanket to give protection through a period of years wool is highly recommended. Dry cleaning is recommended for the cleaning of all types of blankets in order to preserve their size, color, and desirable texture.

The size of blankets is another point to be considered in connection with durability. Blankets that are too short to be tucked in securely at the foot of the bed and leave adequate length to be drawn up over the shoulders are under a con-

stant strain during use. A blanket 84 inches long is considered adequate in most instances but an extremely deep mattress might necessitate the use of a 90-inch blanket.

If a single blanket in a size 60 x 84 inches is chosen, this blanket should weigh not less than two and three-quarters pounds. A 66 x 84-inch size in a single blanket should weigh not less than 3 pounds, and one 72 x 84 inches should weigh not less than three and one-half pounds. These weights are given as the minimum amounts of wool that will be found in a warm, strong blanket of the sizes given. Slightly heavier blankets, provided they have a long, compact nap held securely in the fabric, should furnish added protection from cold, and wear an additional number of years. (See page 499.)

The beauty of a blanket is sometimes the most important consideration of the purchaser. Fluffy, two-tone blankets or those in one color, finished with wide satin bindings, may be chosen on appearance only. The finishing of the ends of blankets is an important point in the consideration of beauty and also durability. It must be understood that many satin bindings will have to be replaced in a few years and that similar material with which to rebind them is expensive and difficult to obtain. Sateen bindings usually wear longer than satin. A crocheted edge is durable, and, if the ends are securely fastened, should withstand the same wear as the rest of the blanket.

The extra blanket is used today to add a note of color. For this purpose the lovely materials woven with one side rayon and the other side wool permit the desired combination of beauty and warmth.

Launderability. To maintain the softness and fluffiness, blankets must be aired frequently and great care must be used in cleaning them. If a blanket has been chemically treated to protect it from moths, it may be necessary to have it dry cleaned or to have it re-treated after each laundering.

Large blankets are difficult to launder at home by hand, and many types of washing machines tend to felt blankets as a result of the tumbling they give. All well-equipped laundries have special machines built to minimize the pounding

or felting action. These laundries are also prepared to thoroughly brush up the nap, leaving blankets practically as soft and fluffy as when new.

All handling of blankets must be done as gently as possible to prevent felting or matting of the fibers, as this makes fabrics thick and harsh. Blankets should be dried where the air is circulating freely but not where it is extremely cold or hot. In placing blankets on the line to dry some prefer pinning the ends; but, whether folded over the line or pinned by the ends, they should not be stretched or even placed smoothly where fastened. The loose part will tend to draw up as it dries and will be narrower than the pinned part unless this is fullered slightly on the line before pinning.

To obtain the best results blankets should be turned while drying. Hang them the other side out and reverse from ends to the middle or from crosswise to lengthwise. This will keep them in better shape. Never hang blankets so that one side has to bear the entire weight, for the yarns may break under the great weight. Never hang blankets outdoors when there is a strong wind blowing, as the selvages may be damaged.

What information is available that may serve as a basis in blanket selection? This is a question of utmost importance to the housewife and one for which there is no brief, definite answer. The characteristics of the fibers, the construction and finish of the fabric, and the size and weight of the blanket must be taken into consideration. There is evidence that the manufacturers recognize the fact that the consumer is interested in adequate informative labels, and the more progressive firms are taking the lead in supplying this demand. If all of the necessary information is given correctly and clearly on the label, there is still the problem of choosing the best value for the money and the blanket most nearly suited to the individual need. In the absence of satisfactory labels, some information may be gained from inquiries and inspection. The size of the blanket and the fiber content are always given.

The weight of the blanket is seldom stated on the label but may be obtained from the salesman. One should request this information and, in the absence of facts concerning breaking



Courtesy Laundryowners National Association of the United States and Canada

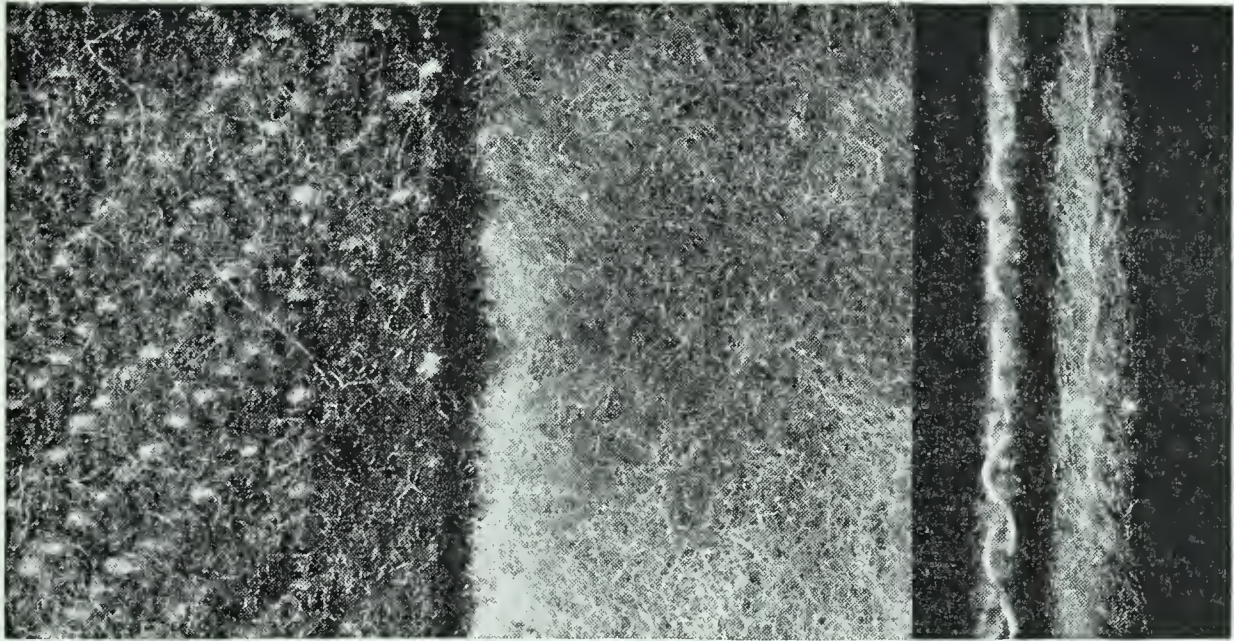
Unevenness in construction of material may result in uneven shrinkage.

strength and warmth, remember that twelve ounces per square yard is the minimum mass of wool fibers which can be made into a blanket that is both warm and strong. High-quality blankets are made of long fibers constructed into a compact fabric and finished with a deep, compact nap. If a small portion of the fibers of the nap, pinched between the thumb and fingers, will sustain the weight of the entire blanket, the fibers are of a length sufficient to permit the amount of finish given the blanket, and also to hold the nap securely in the yarn. A

comparison of the texture of several blankets will permit one to judge the fineness or coarseness of the fibers.

Uneven shrinkage often occurs in blankets in the construction of which heavy and light-weight yarns or yarns of different types are used. This may be a part of an all-over design but usually is found only in the border. The uneven shrinkage results in unsightly blankets, narrower in spots. To avoid this choose a blanket in which only one size and type of yarn is used in any one direction. (See illustration above.)

No definite price range can be given within which one may expect to obtain a blanket that will possess all of the desired qualities. However, an all-wool blanket, constructed of a sufficient mass of long, new fibers to be warm, strong, and durable, will be in the upper price range. The price should be



Highly magnified surface and edge view of blankets, showing effect of napping.

lower in direct proportion to the percentage of cotton or synthetic fibers used. The quality of the wool used also affects the price. Only the cheaper blankets are likely to contain old or reused wool. The larger sizes are more expensive but, up to a certain point, they are proportionately more durable and offer greater protection.

In an effort to develop a classification of blankets that might serve as a buying guide for household purchasers, Hays analyzed forty-three blankets and formulated the classification on the basis of fiber content and weight per square yard.

The consumer could purchase a blanket to suit her needs if, in regular merchandising, blankets were classified and known to meet or exceed a given standard. Then she could compare a Class A all-wool blanket with a cotton-warp wool-filling blanket in Class C, not only on the basis of price, fiber content, and general appearance, but she could learn that the A is heavier, somewhat thicker, just as strong, permits as much air but not quite so much heat to pass through as does the Class C fabric. Similarly, she could compare a Class D with an all-cotton blanket of either Class E or F, or even with a Class B all-wool blanket. She would know that Classes A and C are stronger fillingwise than the other

PROPOSED SPECIFICATIONS FOR SIX CLASSES OF HOUSEHOLD BLANKETS ¹

CLASS OF BLANKET	NUMBER TESTED	MINIMUM REQUIREMENTS						MAXIMUM REQUIREMENTS		
		Yarns per Inch		Breaking Strength *		Weight per Sq. Yd.	Thickness	Air Permeability	Heat Transmission	Loss in Strength After Abrasion
		Warp	Filling	Warp	Filling					
A. All wool weighing 12 oz. more/yd.....	15	24	16	30	20	12.0	0.120	Cu. Ft. per Min. per Sq. Ft. per Lb. Pres. Diff.	Cal. per Degree C. per Sec. per 1000 Cm.	Per Cent
B. All wool weighing less than 12 oz./yd.....	7	24	16	20	10	8.4	0.080	130	.12	90
C. Cotton warp wool filling.....	11	30	28	30	20	9.4	0.090	130	.12	60
D. Between 5% and 25% wool.....	15	32	20	26	10	6.4	0.070	150	.14	10
E. All cotton above 7 oz./yd.....	9	36	24	30	10	7.0	0.090	100	.14	10
F. All cotton below 7 oz./yd.....	11	26	20	20	10	4.2	0.040	180	.17	50

* Grab method.

¹ Margaret B. Hays, "Suggested Consumer Specifications for Six Classes of Household Blankets," *Rayon Textile Monthly*, Vol. 20, No. 2 (1939), pp. 95-97.

four groups, that Classes D and E are more resistant to abrasion; whereas Class F is the lightest in weight.¹

Comforts. Comforts with filling of cotton, wool, or eider-down make warm covers that are preferred by some. Comforts may be covered with cotton, silk, or rayon fabrics that are light in weight. If the inner filling or batt is first covered with a light-weight cheesecloth, firmly fastened before the outer cover is put on, the comfort may be re-covered when it has become worn, and will serve as well as new.

Coverlets or bedspreads. Coverlets or bedspreads furnish unlimited opportunity for individual choice as to material, color, size, and shape. Cotton, wool, rayon, and blends of these all are in common use. The cotton fabrics most popular for bed coverings include piqués, Jacquards, damask or satin weaves, crashes, and crinkle crepes. Candlewick spreads, with their tuftings in self or contrasting colors, are also familiar. The wool fabrics suited to this purpose are commonly woven from mohair fibers. As a fabric, mohair is wrinkle and soil resisting, cleans readily, and wears well. It is available in numerous interesting patterns of which the stripe is perhaps most popular. Rayon and cotton spreads have gained popularity, and because of the pleasing sheen and interesting color pattern these have been widely bought. Many people have been disappointed in rayon spreads because those purchased had a design with long floats that scuffed and lost luster, and scalloped edges that pulled and frayed, the whole spread proving a constant laundry problem. If rayon spreads are to be purchased, they should be of good grade, closely woven, firm textured, and the edges should be finished so that the probability of fraying will be slight.

Points to be considered in buying bedspreads include size, appearance, suitability, and durability. Sizes can be determined only with definite information concerning the height and width of the bed. For beds of regulation height the following sizes are suggested:

¹ Margaret B. Hays, "Suggested Consumer Specifications for Six Classes of Household Blankets," *Rayon Textile Monthly*, Vol. 20, No. 2 (1939), pp. 95-97.

For single bed:

63 to 72 inches wide.

116 to 120 inches long preferred. This provides the length regarded as desirable for the covering of the pillow.

For three-quarter bed:

72 to 80 inches wide.

Same length as cited above.

For full-sized bed:

81 to 90 inches wide.

Same length as cited above.

The appearance of the spread or covering is not infrequently made the basis of choice. Certain colors are popular in spreads as they become key colors or accent colors in bedroom decoration. The character and size of the design, the paneling employed, and the use of tucks or bindings are responsible for the impetus or lack of impetus to popularity that style may bring. In the consideration of most people suitability far outweighs style notes in importance. The coverlet should be bought with the room in which it will be used in mind. For example, a boy's room needs a durable, practical spread, readily cleaned, and neutral in tone, wholly different from the delicately tinted paneled taffeta coverlet that his sister might desire for her room. Spreads of cotton, mohair, and some types of rayon may be expected to give from four to six or seven years of heavy service, the record for durability being held by those of mohair. True economy lies in buying durable fabrics from which long life and satisfaction may be expected.

The laundering of spreads is governed by the type of fiber, the texture and design of the cloth, and the finish of the spread. The details that must be considered in the care of fabrics are given in Unit Three of this section, page 528.

Suggestions for the Laboratory

Select and compare specimens of bleached and unbleached sheeting. Compare price per square yard, weight, ends and picks, and breaking strength.

Obtain information concerning price and quality of blankets available on the market. How are the blankets labeled?

PROBLEM 5. HOW DOES THE CONSTRUCTION OF CARPETS AND RUGS PRODUCE A VARIATION IN QUALITY?

What type of rug will best meet my need? Which one will wear the longer? For a given expenditure, which one will be the better purchase? The individual interested in buying carpets or rugs is concerned with their durability or wear-life. Anyone familiar with household affairs knows that the shuffle and scuff of shoes not infrequently loaded with dust and sand is the daily routine of a carpet; that sunlight may beat upon it unrelentingly for long hours; that the drag, dig, push, and shove of chairs and other furniture leave marks not always obliterated by the action of the cleaning apparatus used; and that dust, heat, and high or low humidity take their tax also. Knowing all that will be exacted of their carpets, the two attributes most desired by would-be purchasers are color permanence and surface permanence.

Color permanence will provide a carpet that resists the fading action of the sunlight, bleaching or discoloration from possible spotting, and color fastness to the cleaning processes to which carpets are submitted. Surface permanence provides that its seeming depth of pile be retained and that the carpets remain relatively free from both shedding or scuffing of short fibers and from pronounced bending or settling of the surface yarns near the base of the carpet.

The factors that influence the wear-life of carpets are usually classed under two main heads: (1) *the physical characteristics of the surface yarn*, including the fiber blend employed, the construction used, and the dyeing, both as to fastness of dye and effect of the treatment on the fiber; (2) *the construction or weaving procedure followed*. This includes the balance or lack of balance in the foundation yarns employed; the density of surface yarns per inch; and the character of the bind by which the surface yarn is held in place. The relation

of these points to wear-life becomes more evident as the fibers used and the methods of construction are considered in detail.

The importance of reliable information concerning the wearing qualities of a rug is realized when one considers the money spent for rugs as shown by the value of sales, the number of persons employed, and the wages paid in the carpet industry.

SIZE OF CARPET INDUSTRY ¹

	TWENTY-YEAR AVERAGE	1937
Value of sales.....	\$153,000,000	\$150,000,000
Wages paid.....	33,000,000	32,000,000
Pounds of grease wool used.....	115,000,000	147,000,000
Number of employees.....	28,000	31,000

Cotton, jute, paper, or synthetics alone or in combination are the fibers that form the back and add thickness. Until recently wool almost universally constituted all or a part of the pile of rugs; and the wools used even in the more modern machine-made types have been the same Asiatic and other foreign wools employed by the makers of true handmade Oriental rugs. Research has proved that these foreign carpet wools lack the strength and elasticity possessed by clothing or apparel wools but possess the high resilience required of a fiber that will make a satisfactory pile rug. This pile must be somewhat stiff and also springy so that it resists crushing. Another characteristic of a good carpet fiber is its resistance to being twisted, which would cause the pile to fluff out when it is cut. The lack of a natural tendency to collect or retain dirt particles is of prime importance in rug fibers. Extensive research on the causes of soil retention has shown that fibers with comparatively smooth circular cross section and large diameter retain less soil than small fibers with many channels in their surface.

¹ Joseph Alexander Truitt, "The Carpet Trade Needs Rayon—Is Rayon Ready?" *Rayon Textile Monthly*, Vol. 21, No. 1 (1940), pp. 33–34, 37; Vol. 21, No. 2 (1940), pp. 101–103.

Rayon is being used to form the pile of rugs but until recently no fibers had been tried that possessed the desired characteristics. Rayons have a tendency to form a thin tuft rather than to fluff out and so far they seem to soil more readily than wool. However, with the continued efforts of research workers it is claimed that a fiber has been produced which possesses all the desirable qualities of carpet wool and lacks some of the undesirable ones. This rayon fiber is on the market, in carpets and rugs manufactured for home use.

There are two major obstacles in the way of using normal rayon fibers in fabrics which are washed only infrequently, as are rugs. Sweeping, vacuum cleaning, or brushing does not remove the soil and dust from rayon fabrics as readily as they are removed from mohair or sheep wool. Staple rayon fibers of $1\frac{1}{3}$ to 7 denier are unsuited for rug fibers as the yarn produced from them makes an extremely soft fabric. However, coarser rayon staple fibers have a texture similar to wool and may wear as long or longer than wool. Water-repellent and crease-resistant finishes using synthetic resins add to the wool-like feel of rayon staple fabrics, including rugs.

Microscopic examination has shown that with the irregular surface of rayons, such as normal viscose, the dirt collects in the channels and that these lines of dirt are magnified by the translucent nature of the fiber. A rayon staple fiber, circular in cross section, collects the dirt in a regular form and not in channels.

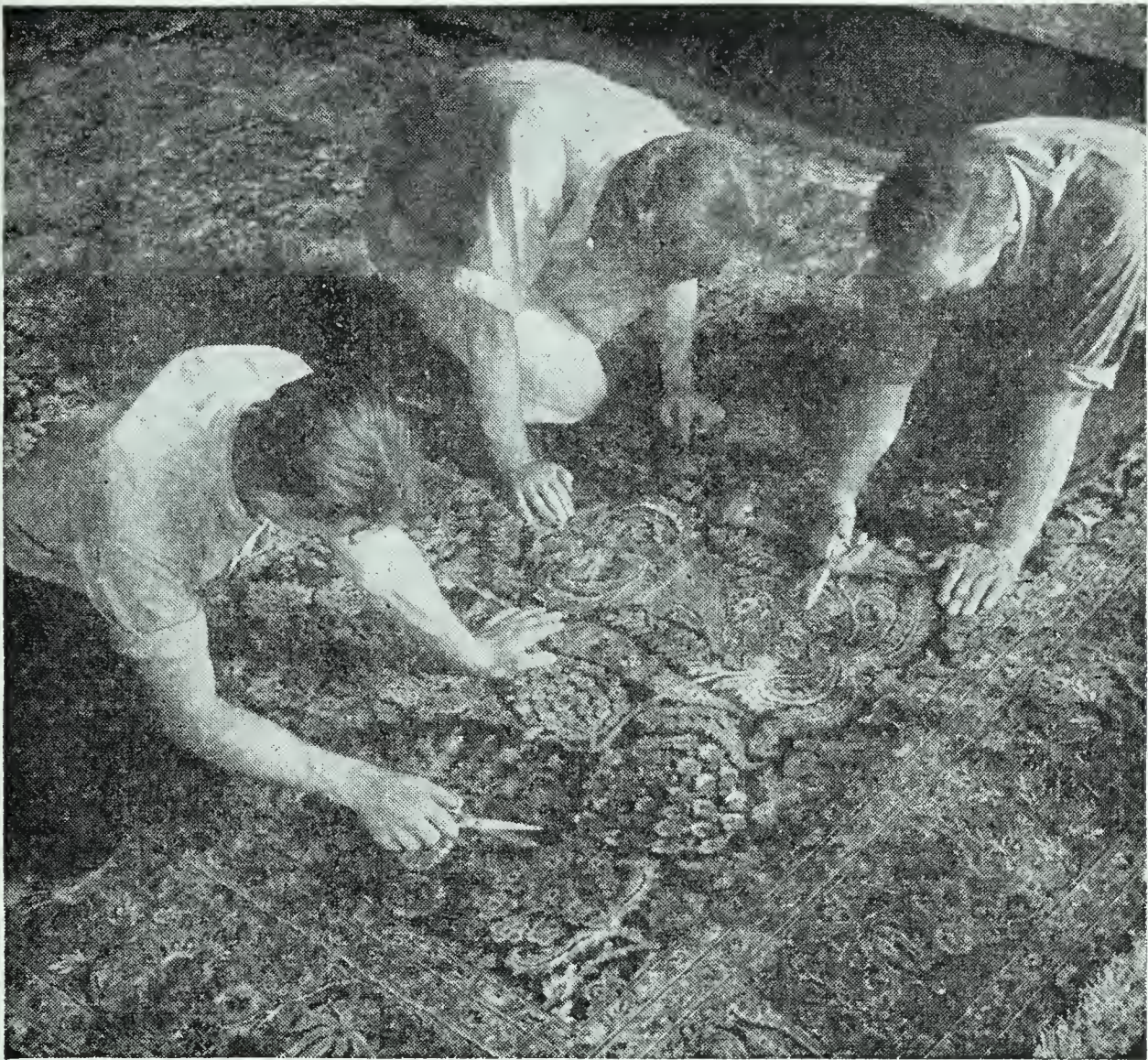
Carpets differ from rugs only in the form in which they are produced. Carpeting is woven in long strips varying from a few inches to several feet in width. It is bought by the yard, in the desired width or in strips which are cut and sewed into the desired size and shape, or used as runners. Rugs are bought in finished form, in varying sizes and shapes. These may be made up of strips sewed together or may have been constructed in one piece. As the type of construction is the same for both, in this discussion the terms carpets and rugs will be used interchangeably. Broad loom simply means that the rug was woven in full width on a loom as wide as the width of the rug, which may be eighteen feet.

Carpets are classified according to the manner of construction into several groups. Two of these, Oriental and European hand-tufted, are made by hand. The important machine-made rugs found on the market today are Brussels, Wilton, tapestry, Velvet, Axminster, and chenille. Ingrain carpets were once widely used but have disappeared because of their poor wearing qualities.

Brussels, Wilton, tapestry, and Velvet carpets are constructed with either a cut or uncut pile formed of warp yarns looped over wires. The closeness of construction is designated by the number of rows of loops per inch in length and the number of loops across the width of the carpet. The number of rows per inch in length is given as the number of wires, and the number of loops per inch in width is spoken of as the pitch of the carpet. A loop is known as a *point* and the number of points in a square inch is obtained by multiplying the number of the pitch per inch by the number of wires per inch. The number of weft yarns per loop that hold the pile in the fabric is spoken of as the shot of the carpet. These terms are used to describe carpet construction.

Brussels and Wilton carpets. Brussels and Wilton carpets are of similar construction. In them a separate warp pile yarn is used for each color appearing in the design, and the colors not brought to the surface are held in the body of the rug. This is an expensive type of construction but these rugs are considered the best machine-made type of rug available on the market. Besides the pile warp, two other sets of warp are required. The second group of warp yarns, usually of cotton known as the *chain*, interlaces with the filling in the construction of the foundation fabric. The third group is carried straight through the cloth simply as “stuffer” yarns being added for body and stiffness. In a true Wilton or Brussels, pile yarns of the different colors are always carried in the body of the cloth.

These colored pile yarns are wound on spools and each color is placed on a frame in the back of the loom. The Jacquard attachment is required to lift the yarns that appear on the surface and form the pile for each row of loops. Only six

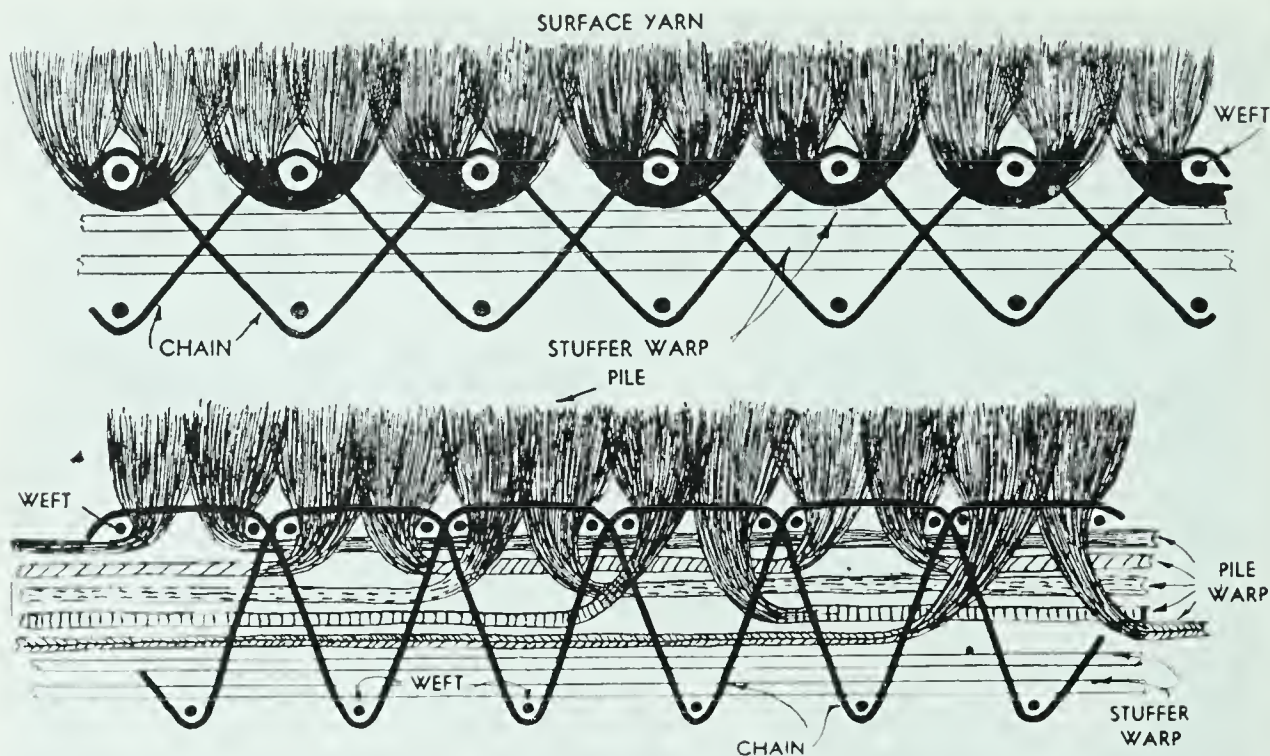


Courtesy F. S. Lincoln

Putting finishing touches on rugs at the manufacturing plant.

trays known as frames are used, but more colors can be employed by a method known as *planting* in which the extra colors replace a part of the spools on a frame. By this method many colors may be used. In a five-frame construction four yarns would always be carried in the body of the rug. The five yarns, one of each color, would be drawn in groups through the reed spaces. As in all warp pile weaving done over a wire, the wire is inserted in the shed. In Brussels construction these wires have a smooth end and the loop is left uncut when the wire is withdrawn.

Brussels. A high-grade Brussels is constructed with from 81 to 90 points per inch and two shots per row of pile. The various colored yarns appearing in the same vertical row of loops



Weaving diagrams of some domestic carpets. Top, velvet weave carpet, 2 shot. Bottom, Wilton weave carpet, 5 frame, 3 shot.

are carried in the body of the carpet when not appearing on the surface. This increases the quality of the carpet; hence the quality is indicated by the number of these yarns that appear in a vertical row and must be drawn into one dent of the reed. These uncut pile carpets give exceptional wear but lack the soft texture of the cut pile. This construction is used in a long pile in imitation of hand-hooked rugs and in forming a design with cut pile.

Wilton carpets. Wilton carpets differ from Brussels in that the pile yarns are cut when the wires are withdrawn. They usually have a finer construction, as this is necessary to hold the cut pile firmly in place. A high-grade Wilton, as illustrated above, is considered to be one of the best machine-made carpets. The large number of yarns and the inclusion of the pile warp in the body of the fabric for relatively long distances give extra thickness to the rug. The cut pile permits unusual depth of color. This type of rug constitutes approximately 9 per cent of the rugs sold. The following specification indicates the quality considered necessary for a satisfactory carpet or rug of this type.

The following was taken from DDD-C-71a, July, 1934.

FEDERAL SPECIFICATION FOR CARPETS AND RUGS: WILTON

B. Types.

B—1. This specifications covers four types of fabric as follows: Type I, Worsted Wilton rugs, six frames; Type II, Worsted Wilton carpets, five frames; Type III, Wool Wilton carpets, two or three frames; and Type IV, Wool Wilton rugs and carpets. (Saxony type.)

C. Material and Workmanship.

C—1. Wilton fabric. Type I and II shall be woven from best quality carpet worsteds with warp, filling and stuffers of cotton; Type III from wool carpet yarn, with warp and filling of cotton and with stuffers of jute cotton, twisted paper, or other suitable material; and Type IV from wool carpet yarn with warp, filling and stuffers of cotton. All weaving shall be evenly done in a neat and workmanlike manner.

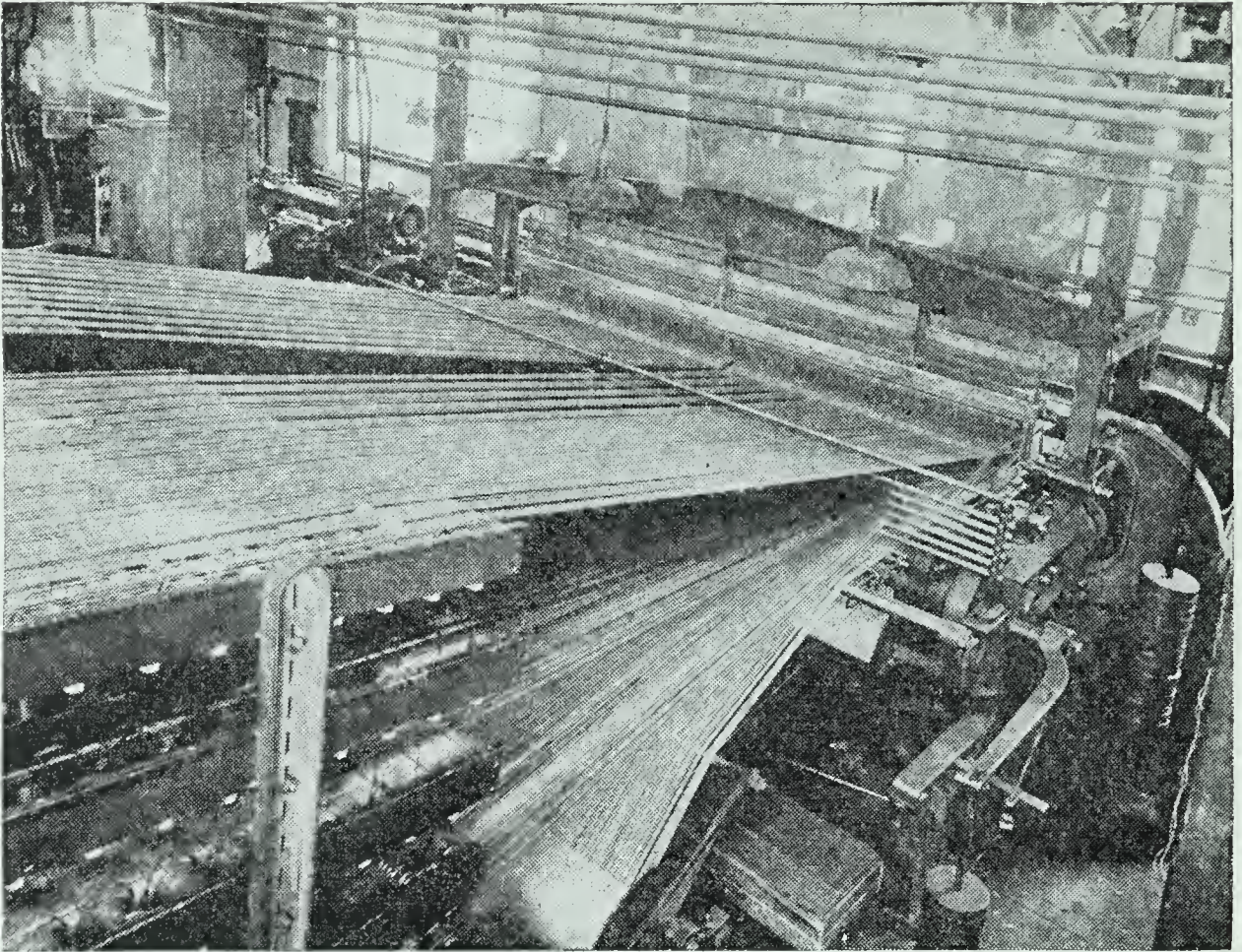
D. General Requirements.

D—1. Definition. A genuine Wilton fabric must be woven on a Wilton loom always known as such; that is, a loom with a Jacquard automatically selecting and raising independently each individual colored thread over the cutting wire, for the purpose of forming the pattern, which pattern must always consist of two or more colors, yarn dyed in the skein or stock and drawn from a creel. The threads not selected by the Jacquard to make the pattern will always be found running through the body of the fabric. Under no circumstances can a fabric be a Wilton where the design has been printed in either the yarn or the woven fabric by any mechanism whatsoever.

E. Detail Requirements.

E—1. Worsted yarns shall be spun from fine, long-fibered blended wools, thoroughly cleansed of all animal fat and foreign substances, and combed until short fibers are removed and the long fibers are straightened. It shall then be drawn and spun until the resulting yarn is fine, supple, elastic, uniform in diameter and strength, and soft to the touch. All worsted yarns shall be three-ply thread, each ply consisting of two strands twisted together.

E—2. Wool yarns shall be carded and spun from blended filling wools, thoroughly cleaned of animal fat and foreign sub-



Courtesy Hardwick and Magee Co.

The many threads of the yarn that go into the Wilton fabric are shown coming from the five frames required in the design.

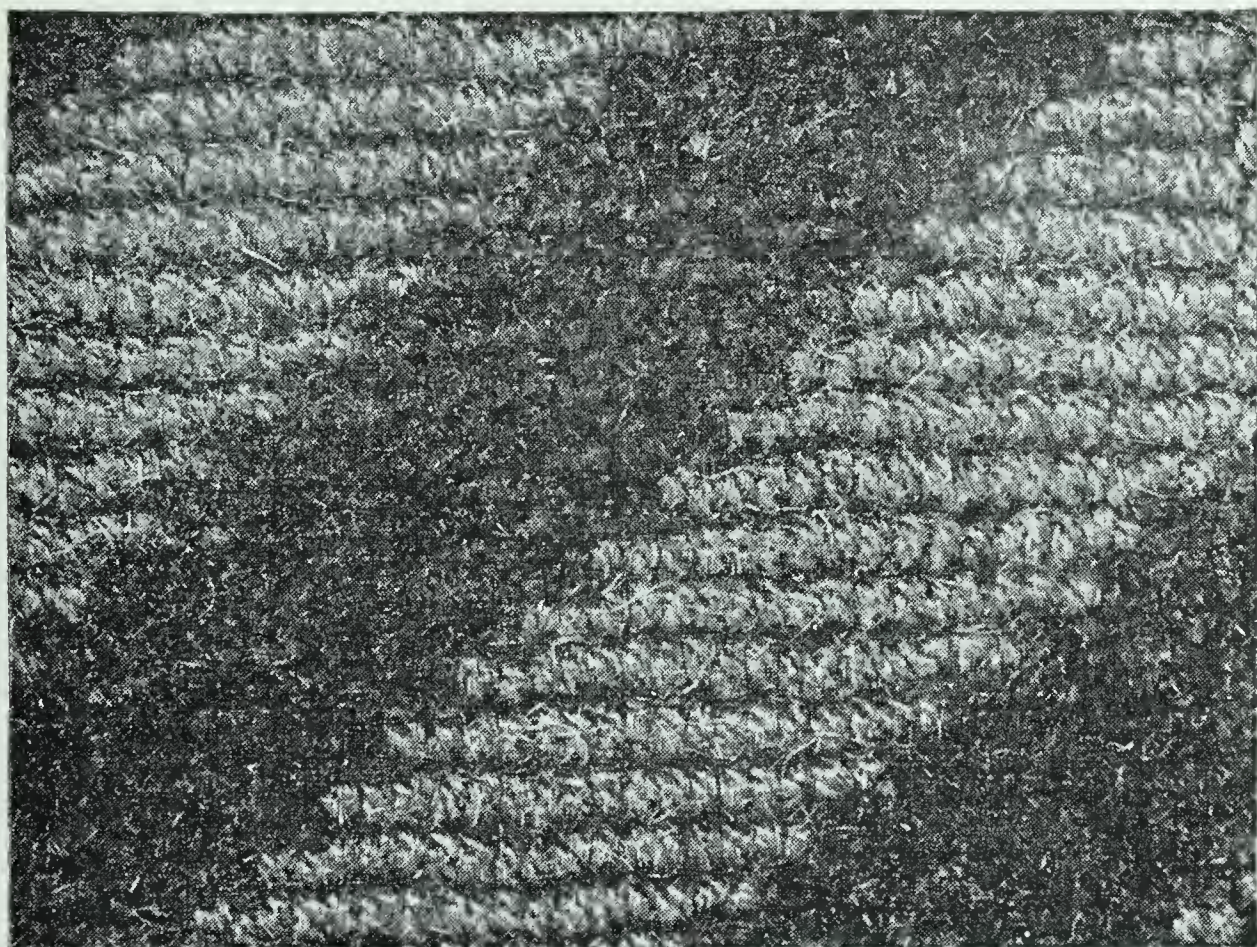
stances. It shall be carded and spun until the resulting yarn is supple, elastic, and uniform in diameter and strength.

E—3. Dyeing. Pile material shall be evenly and thoroughly dyed with permanent sun-fast dyes of the alizarin type or equal.

E—4. Patterns for rugs shall be of the latest most desirable type. It is the intention to secure patterns from manufacturers' standard lines.

Tapestry and Velvet rugs. Tapestry and Velvet rugs as a group differ from Brussels and Wilton in that there is but one yarn running down the length of the pile instead of a separate yarn for each color used. The design is printed on the pile warp by a method known as *drum printing*, or by roller printing on the woven fabric.

In drum printing the design is placed on strands of the pile before the rug is woven. Undyed yarn is wound on huge



Courtesy The Hoover Co.

A texture carpet in which the design is produced by combining cut and uncut pile. This carpet was woven on a Wilton loom and the cut and uncut pile appear in alternate rows. A soft twisted single-ply yarn is used for the cut pile and a rather loosely spun 3-ply yarn for the loop pile.

drums about 39 feet in circumference and wide enough to permit the continuous strand of yarn to be wound 330 times around the drum. This will supply one pile yarn for 330 rugs and a drum must be prepared for each warp pile in the rug (See the illustration on page 514.)

For a 9 x 12 foot rug about 400 drums must be printed. The design for the rug is elongated approximately three times as it requires about three times the length of yarn to produce the finished tuft. Printing is done by a rubber roller which turns through the dye in small buckets. A different bucket for each color is moved beneath the drum by a carrier device. The color is printed in a stripe across the width of the drum, thus printing each strand of the yarn. The wheel is revolved by hand and all the stripes of one color are applied before an-



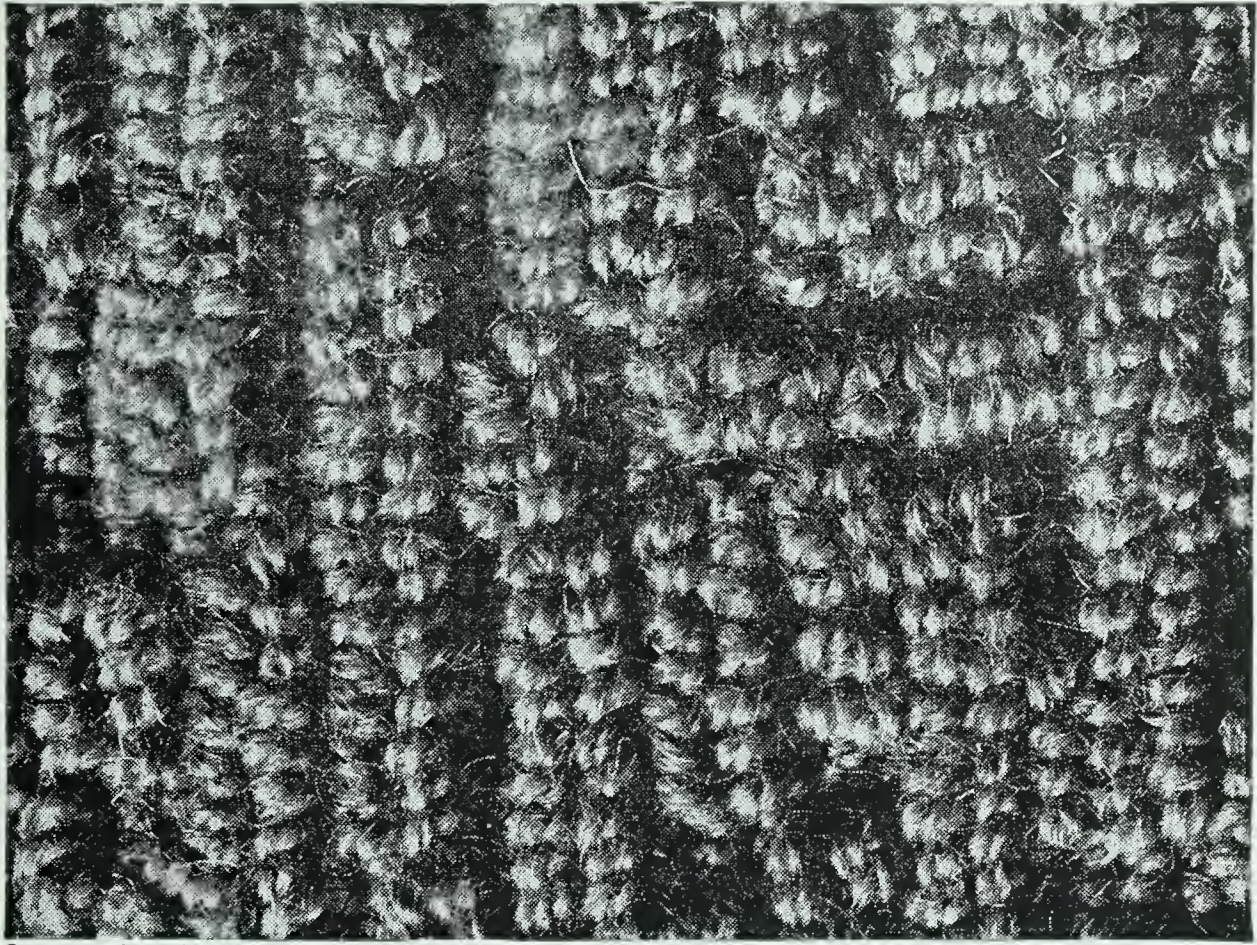
Courtesy Bigelow Sanford Carpet Co.

Elements of the carpet loom consist of heddles, reed, shuttles, and wires in the order named. This is a velvet loom. Much of the plain colored carpet of today is of the velvet weave. Broad looms make it possible to weave fabrics up to eighteen feet in width.

other color is used. When the yarn has been printed, the drum is partially collapsed to facilitate removal of the yarn. The long hanks of dyed yarn are placed on wire trays and the color is set in steam ovens.

The printed pile warp is arranged in correct order and wound onto a beam. This beam takes the place of the bobbins or spools which are placed on the frames for the construction of Brussels and Wilton rugs. As there is only one warp yarn in each lengthwise row of loops, the Jacquard attachment is not used.

Tapestry carpets and rugs are woven over a smooth wire similar to that used in the construction of Brussels, and the loops are left uncut when the wires are withdrawn.

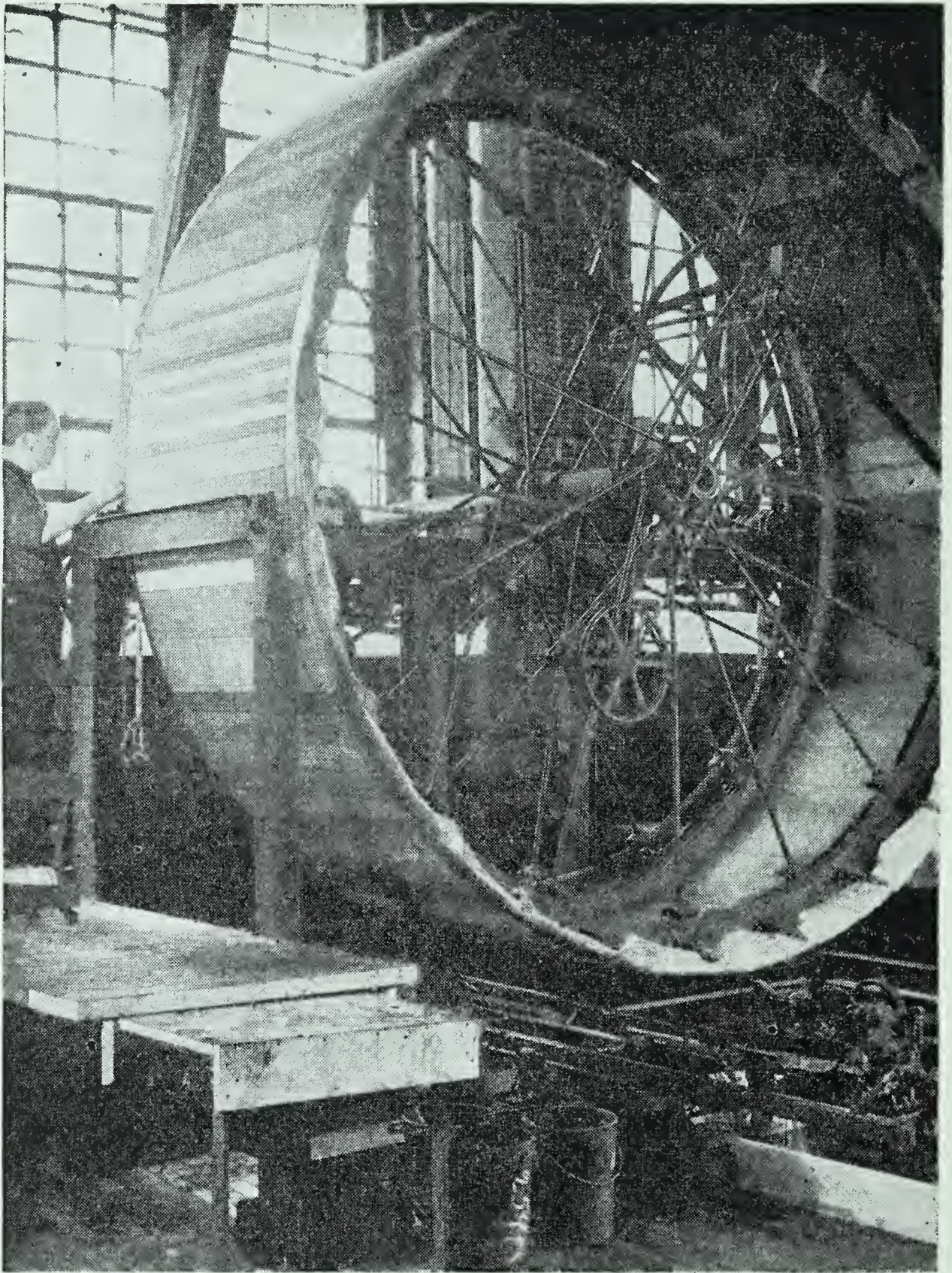


Courtesy The Hoover Co.

This fabric is a product of the Tapestry carpet loom, a texture floor covering in which the design is produced by combining two lengths of loop pile in the same fabric. The short and long loops appear in alternate rows. A 3-ply woolen yarn is used.

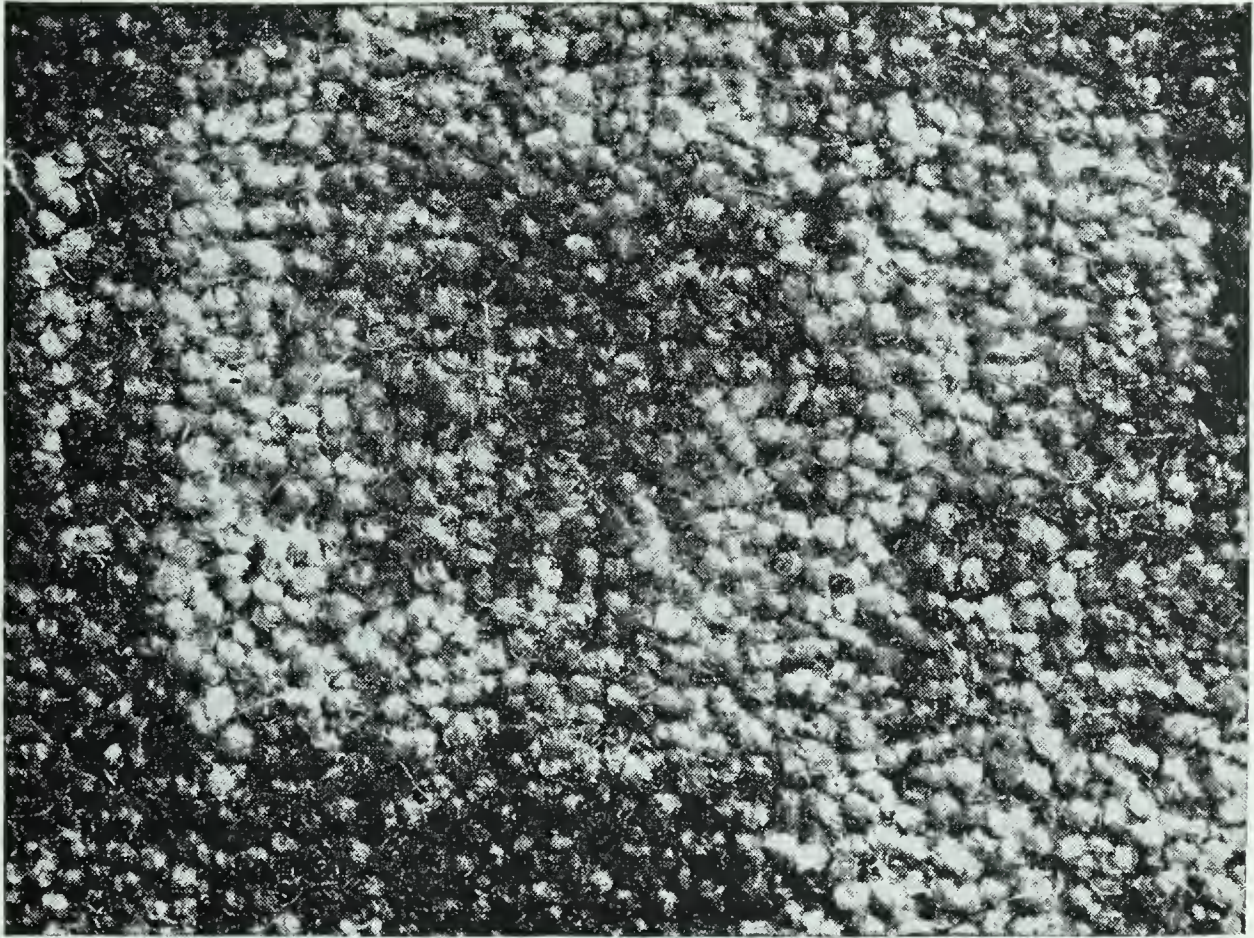
Velvet carpets are constructed in the same manner as tapestry, but there is a knife on the end of the wires over which the loops are formed. When the wires are removed, the loop is cut. Velvet carpets are woven with more shots for each loop of pile than are found in tapestry carpets. A good quality of velvet should have four weft yarns to every loop of pile yarn. Velvets vary from six to nine wires per inch. A six-wire carpet is not considered good quality, however.

Velvet or tapestry rugs may be woven from undyed yarns and the design printed by the roller method into the pile fabric. At one time this was not considered a satisfactory method but it is now being used by some of the largest rug manufacturing firms who claim the design penetrates to the bottom of the pile and is as permanent as the fabric itself. Less than 1



Courtesy Mohawk Carpet Mills

Narrow drum for printing warp for velvet carpet. The printer follows the color indicated on a checked design paper.

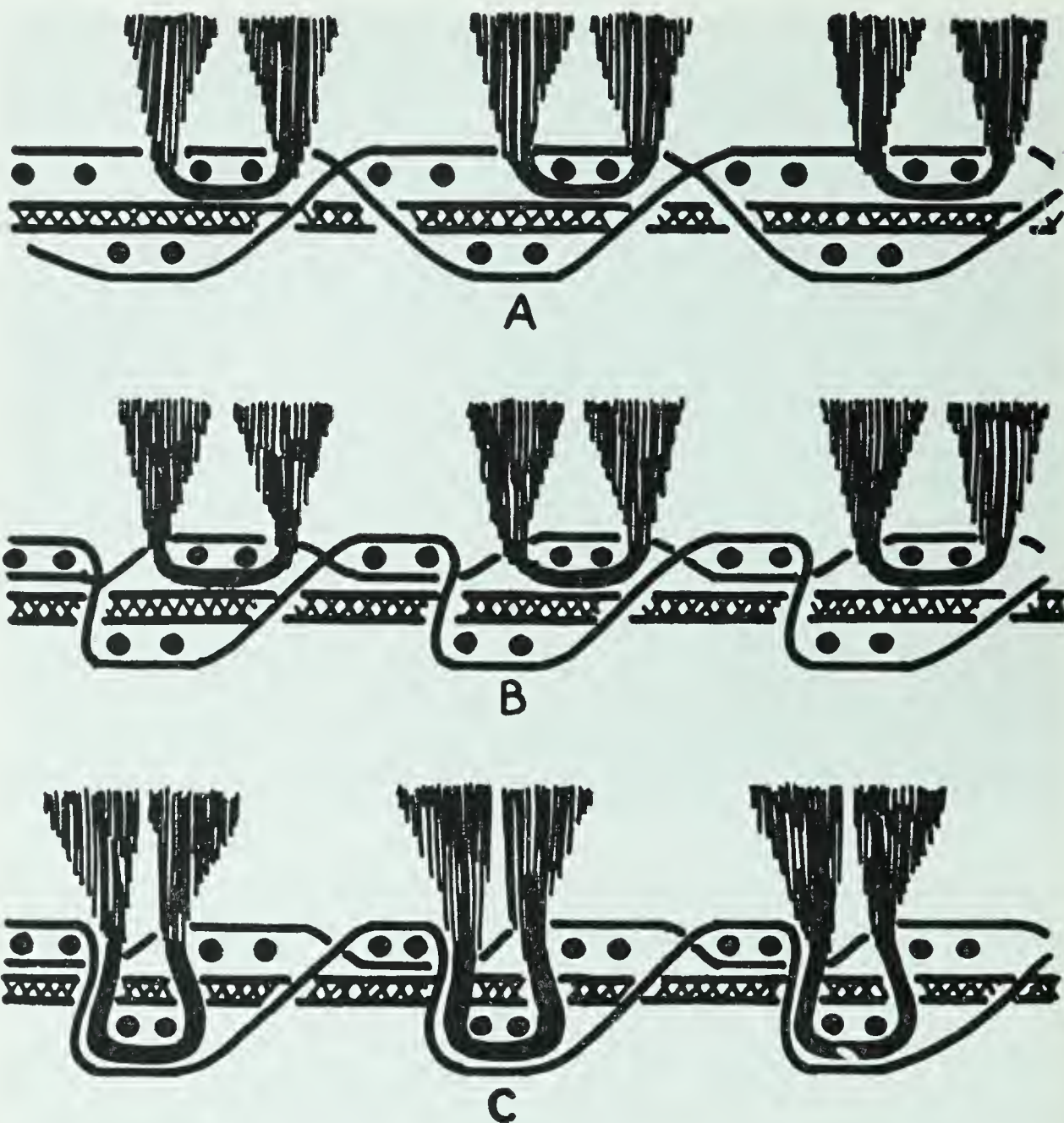


Courtesy The Hoover Co.

Velvet carpet with a $\frac{3}{16}$ inch pile of tightly spun 3-ply woolen yarns. The yarns are drum-dyed, producing the hazy pattern characteristic of figured velvet carpets.

per cent of all rugs manufactured in the United States are of tapestry construction and approximately 30 per cent are velvet.

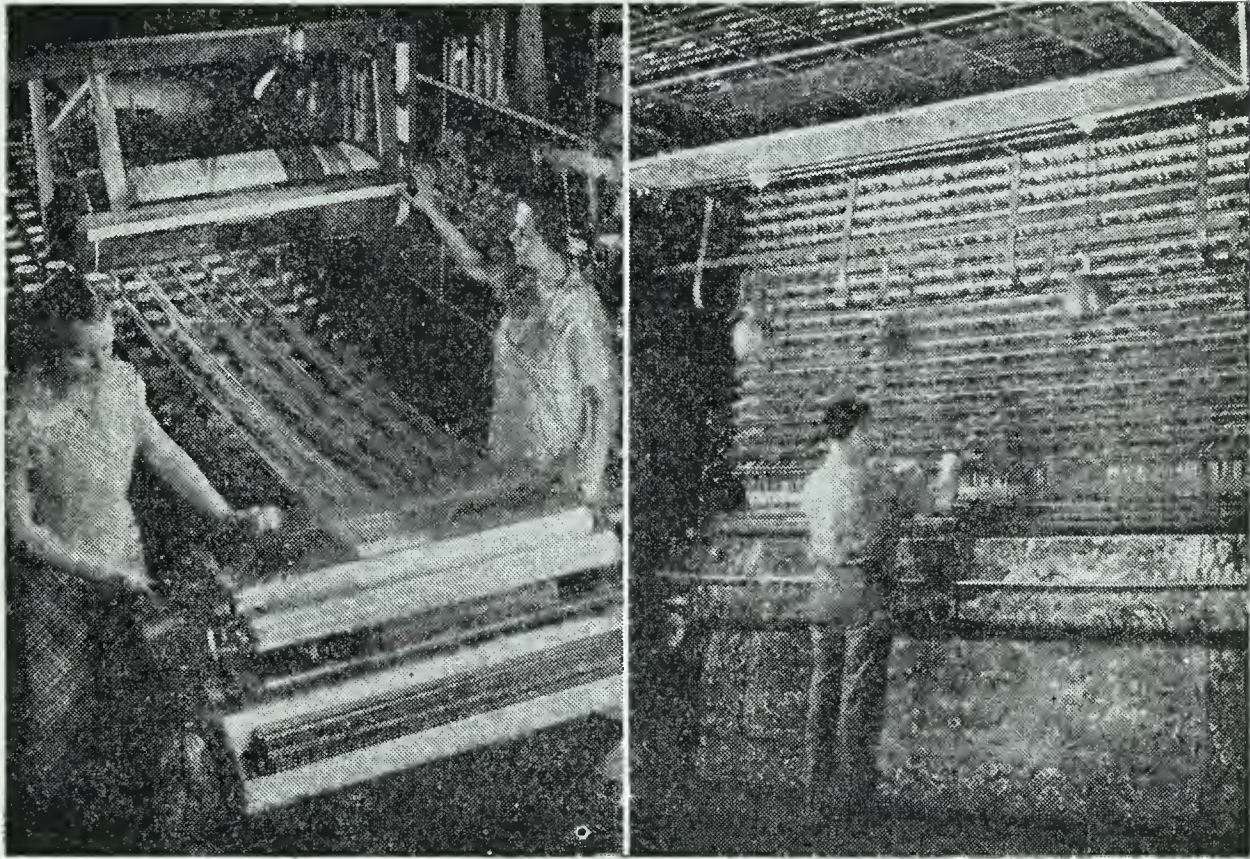
Axminster carpets. Axminster carpets are the result of an American invention which developed from attempts to manufacture by machine an imitation of Oriental hand-knotted rugs. In it are combined wearing quality and appearance at a medium price. This accounts for the fact that 40 per cent of total rug production is of Axminster construction. Though Axminster carpets resemble velvets in some respects, the manner of their construction differs greatly. A cut-wool pile forms the surface, with a linen or cotton warp and usually a weft of jute. Each tuft is automatically cut as it is woven. These loops are securely bound into the body of the carpet by the weft yarns. The peculiar method by which this type of carpet



Three structures of Axminster rugs. All are three-shot, but differ in the interlacing of the yarns. A, Imperial; B, Royal or Gripper; C, a type seldom used, but one that imitates quite closely a hand-tufted rug.

is woven permits the use of an unlimited number of colors and an opportunity for a wide range of designs.

There are three systems of inserting and binding the pile yarns into the ground fabrics, and each gives to the rug its characteristic qualities. These differences are illustrated above. In the standard method of Axminster construction, the differently dyed warp pile yarns in solid color are wound side by side on spools the length of the width of the carpet. A spool must be prepared for each horizontal row of tufts in the de-



Courtesy Bigelow Sanford Carpet Co.

Left, winding spools for Axminster rugs. Observe the pattern above the heads of the workers. The spool is prepared according to the pattern for each row of tufts in the design. Right, weaving an Axminster rug. Each spool presents the yarn for an entire row of pile tufts, each tuft of the specific color planned by the artist.

sign. The number of pile yarns wound on each spool corresponds to the number of pile tufts to be formed in the width of the carpet. The ends of these pile yarns are passed through tubes, and the spool carrying the yarns in correct order for the formation of the design is presented to the loom for use. By a mechanical device, a length of yarn sufficient for one tuft is drawn from the spool and inserted in the shed. The passage of the filling binds the tuft in place. The spool is removed and the next one comes into position. The three pairs of picks bind the tufts in place and a firm-foundation fabric results.

The gripper Axminster loom constructs Axminster carpets by a different method. In this system the yarn is prepared as for the construction of Wilton rugs. The yarns in plain color are wound on bobbins and placed in frames. There is less limitation in the number of frames used. By “planting,” the

number of colors may be greatly increased. The Jacquard mechanism is used to select the colored pile yarn to form the tuft. However, the yarn is cut as each tuft is formed, and the pile yarn is not carried in the body of the rug.

The following was taken from DDD-C-51a, May 26, 1943.

FEDERAL SPECIFICATION FOR AXMINSTER CARPETS AND RUGS

B. Type and Grades.

B—1. This specification covers one type of fabric, Axminster carpets and rugs, in two grades; as specified in the invitation for bids:

Grade A. High quality

Grade B. Extra high quality

C. Material and Workmanship.

C—1. Axminster fabric shall be woven from best quality filling wools with cotton warp and filling of jute, cotton, twisted paper, or other suitable material. All weaving shall be evenly done in a neat and workmanlike manner.

D. General Requirements.

D—1. See detail requirements.

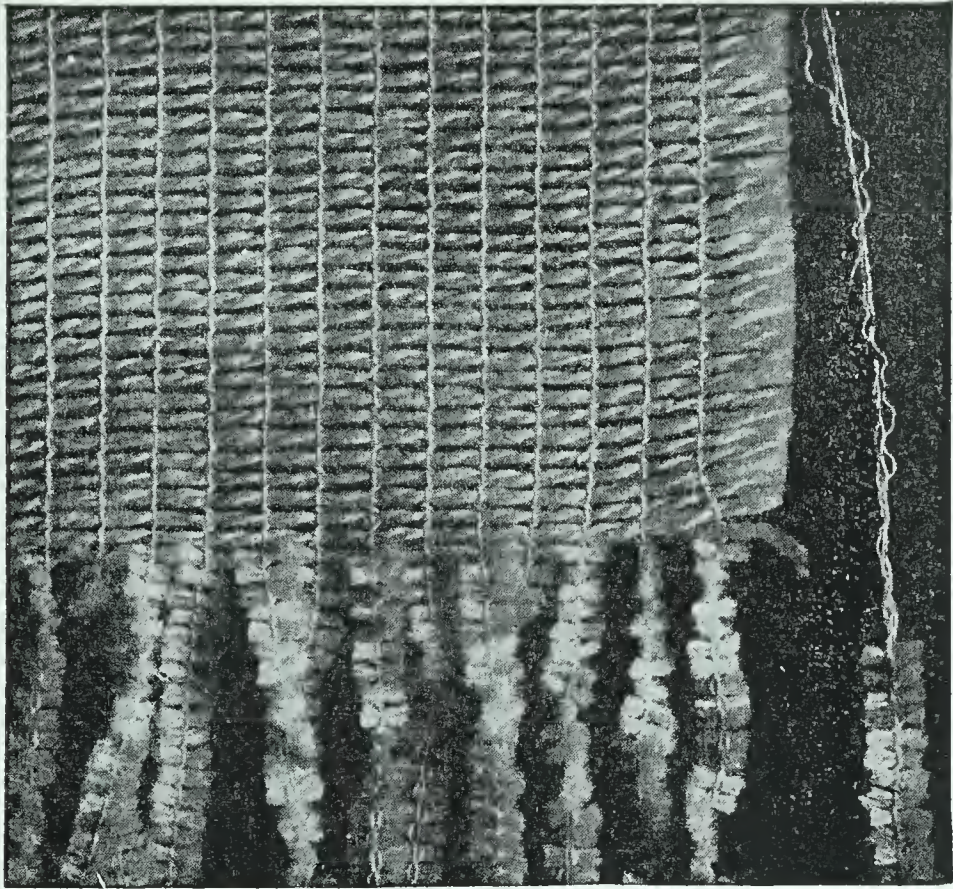
E. Detail Requirements.

E—1. *Pile yarn* shall be carded and spun from blended filling wools, thoroughly cleansed of all animal fat and foreign substances. Yarn shall be supple, elastic, and uniform in diameter and strength.

E—2. *Dyeing*. Pile material shall be evenly and thoroughly dyed to meet fastness requirements.

E—3. *Patterns for rugs* shall be domestic adaptations of the best designs in low-toned and rich colors. It is the intention to secure patterns from manufacturers' standard lines.

Chenille carpets, although quite similar to Axminster in appearance, are thicker and more expensive. A so-called chenille cloth is first woven of a wool filling with a twisted warp spaced twice the distance of the desired height of the pile. (See page 519.) This fabric is so constructed that when cut into lengthwise strips the wool tufts curl naturally. These are pressed in the form of a "V" and steamed, thus forming a chain of cut pile which is laced into a foundation back. The



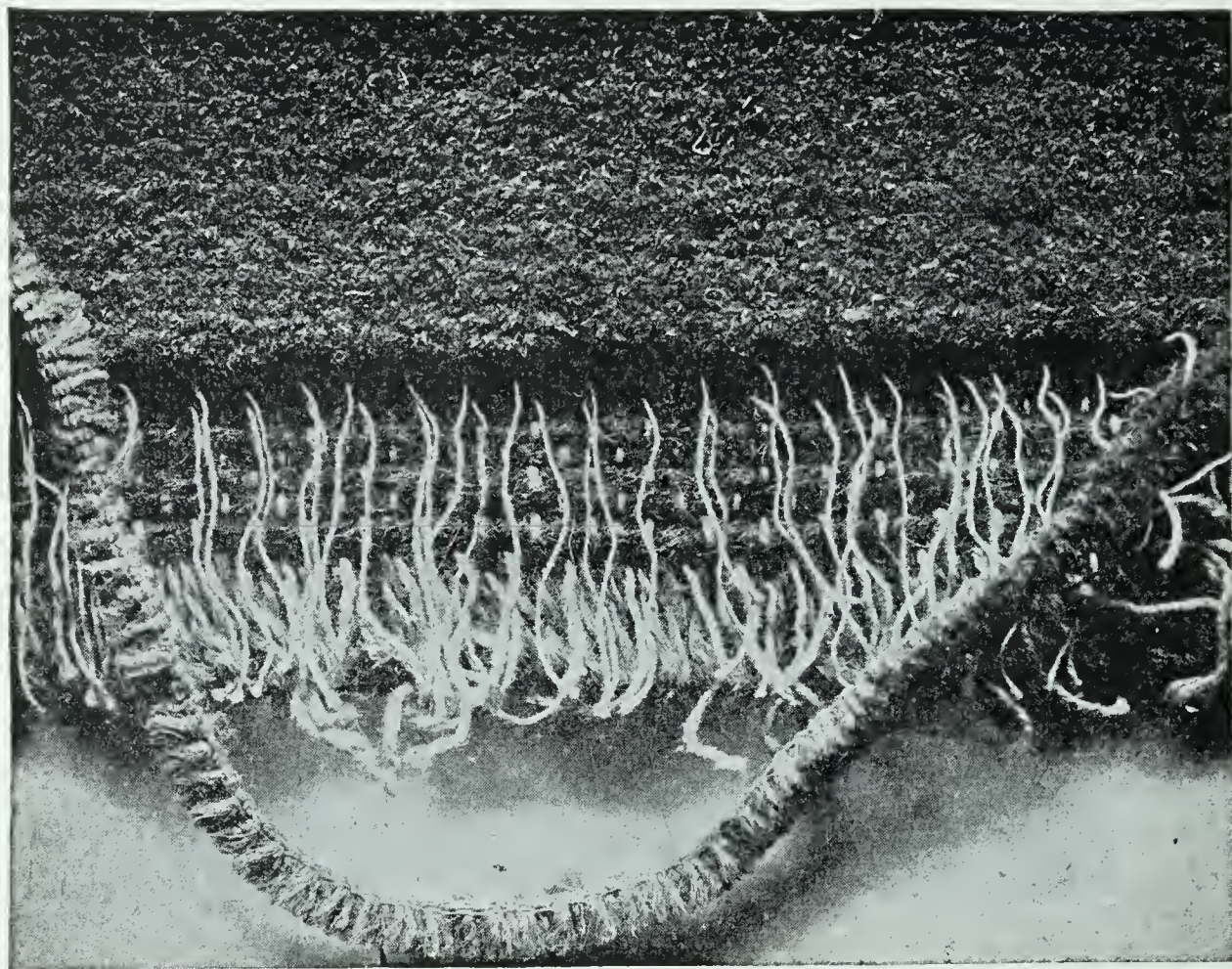
From Grace G. Denny, *Fabrics*, J. B. Lippincott Co., 1947

Chenille cloth from which chenille yarns are made.

strips of cloth, known as fur, serve the purpose of filling pile, the lacing thread being a warp thread. (See picture on page 520.)

Chenille carpets are more expensive than other types because two systems of weaving and a great amount of hand work are required. The strips of fur are carried across the loom by a finger or ring but the chenille is combed through the warp yarns and set by hand. A wide loom requires two or more weavers to comb and set the pile. These carpets can be constructed in any width up to 30 feet and are often made to order and shaped to fit the room. Luxury fabrics in chenille weave are woven plain and carved by hand. The design is often in the form of a border only. The durability of chenille carpets is determined by the firmness with which the strips of fur are laced into the body of the carpet and by the strength of the lacing thread.

Smyrna is a reversible pile carpet which resembles chenille in appearance but is the same on both sides. These carpets are made from strips of fur in which the pile has not been



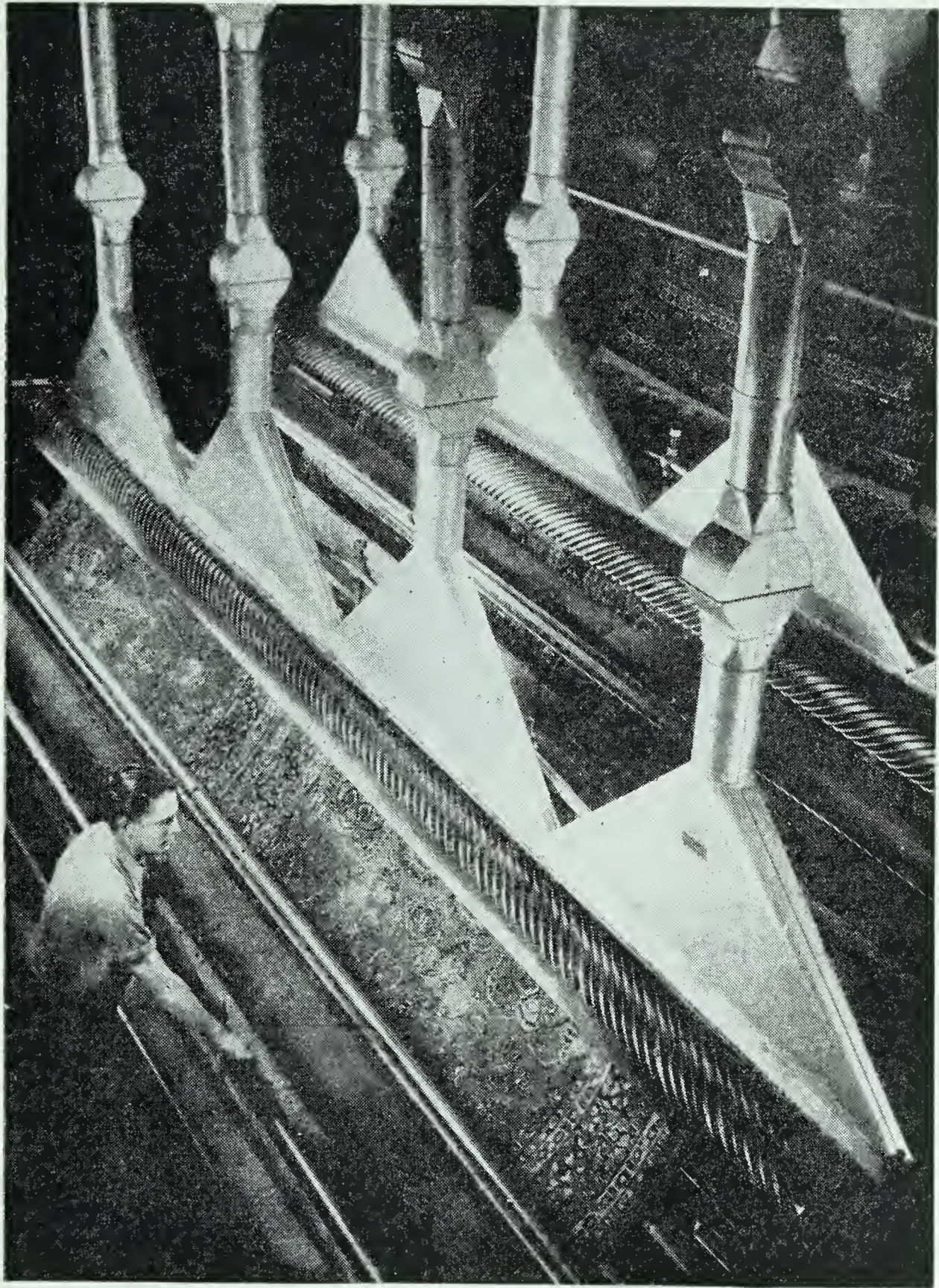
From Grace G. Denny, *Fabrics*, J. B. Lippincott Co., 1947

Chenille rug.

folded or pressed but remains as cut. These strips are woven into the carpet as filling, together with an alternate filling of jute to give body to the fabric. Reused wool is often used in rugs of this type.

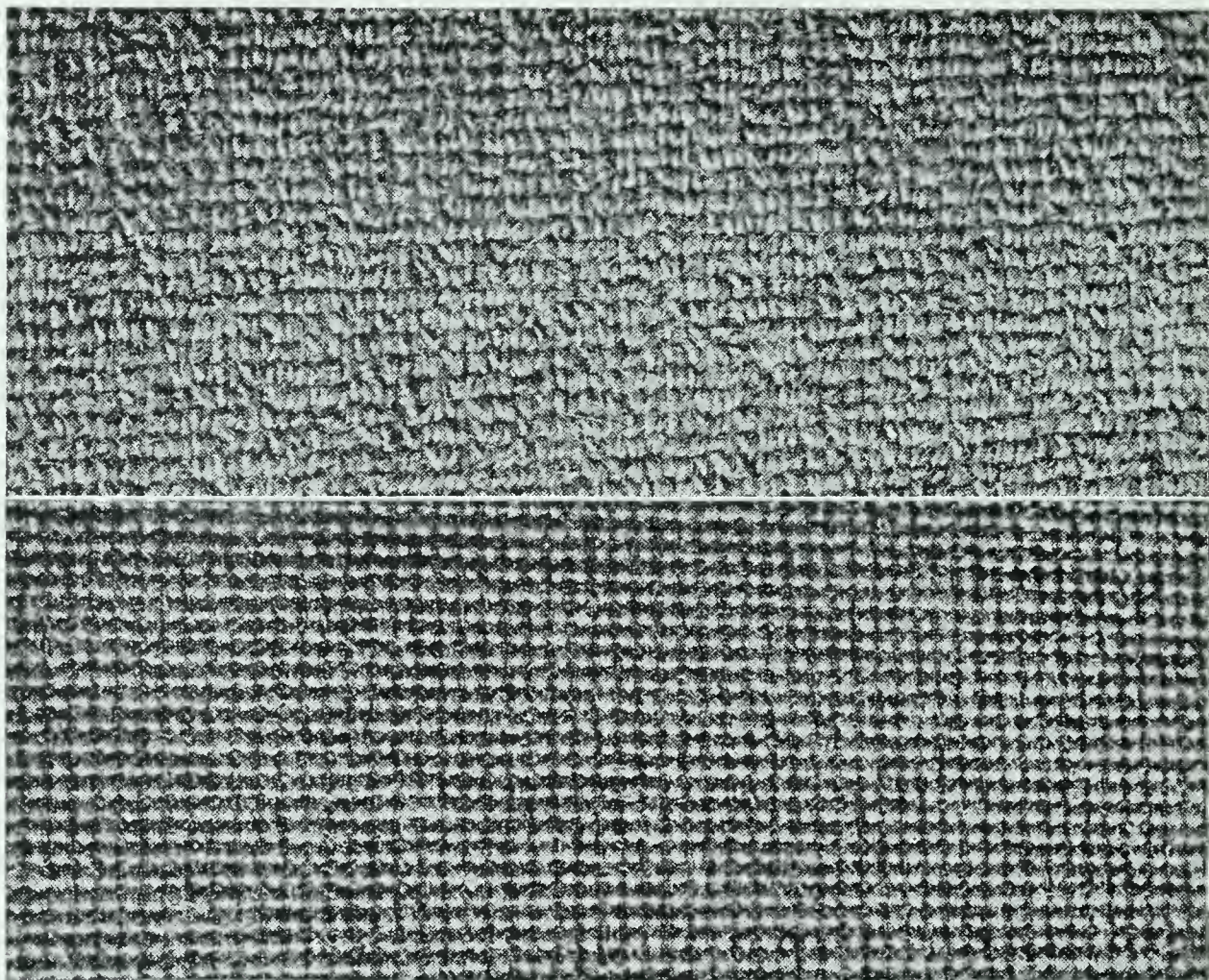
Patent-back carpets. Patent-back carpets, a comparatively recent development for floor covering, are giving good service. One type known as “Lock-weave Broadloom” is woven on regular velvet-carpet looms. Heavy cotton yarns are used for warp, weft, and stuffer yarns. Each tuft of the heavy woolen pile yarn is woven through to the back. After being given the regular finishes, the backs of these rugs are coated with a pyroxylin lacquer. This treatment binds the tufts securely in place so that the carpet may be cut in any direction without raveling. (See the illustration on page 522.)

This make of patent-back carpet is available in four grades, each in a complete line of 27 colors but in 12/4 (9-foot) width



Courtesy Bigelow Sanford Carpet Co.

Shearing the pile. The pile of a rug as it comes off the loom is slightly uneven and must be sheared. Long chains of rugs are sewn together and fed into this machine, like a gigantic lawn mower, which shears the pile to the correct height. Three shearings are necessary to produce the smooth, velvety appearance of the finished fabric.



Courtesy The Hoover Co.

Top, face of fabric; bottom, back of Bigelow Lock-weave rug.

only. These grades vary from $8\frac{2}{3}$ rows per inch and a pile height of $\frac{1}{2}$ inch to 8 rows per inch and a pile height of $\frac{1}{4}$ inch. The pitch in all grades is 216 in 27 inches. One grade is made with a hard-twisted yarn, producing the pebbly surface known as frieze.¹

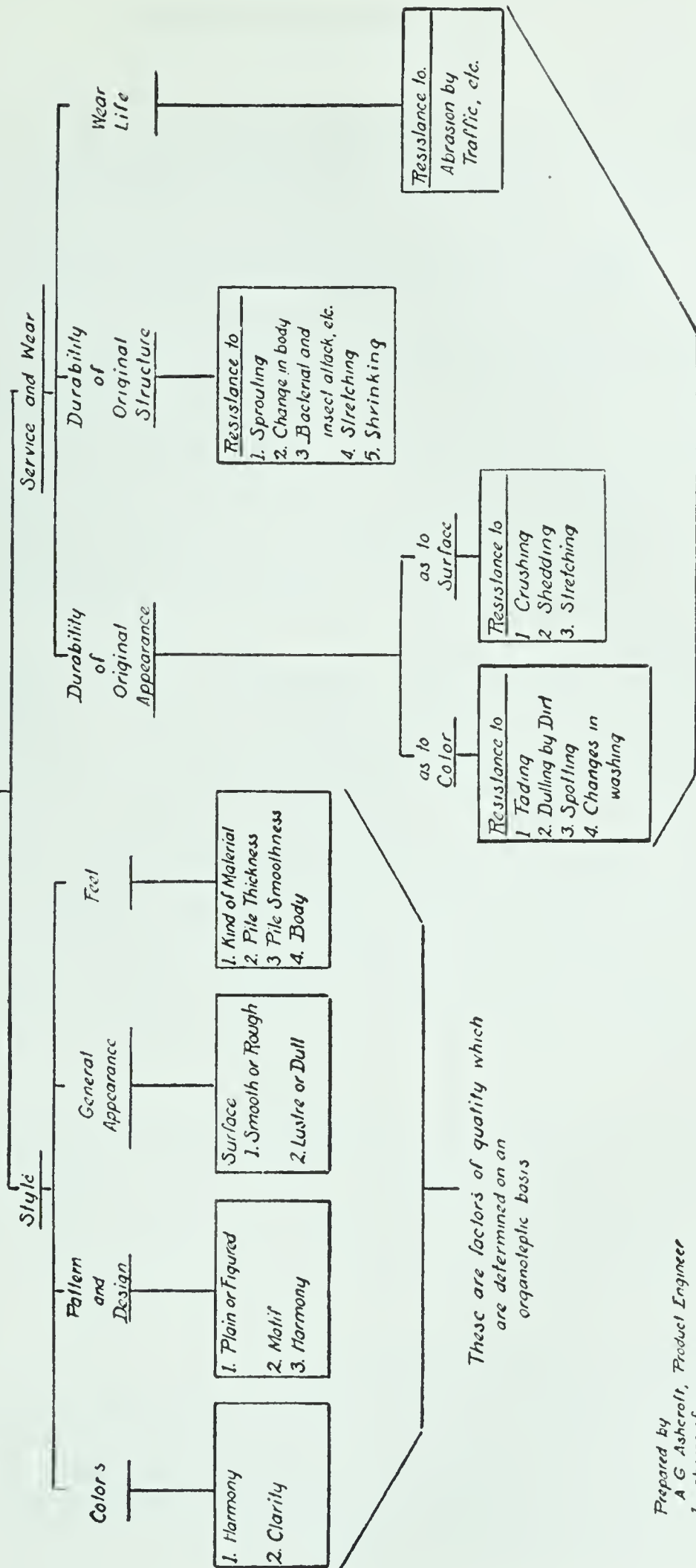
Texture rugs and carpets.² Texture floor coverings have been in the process of development since 1931, or even earlier. It was 1935, however, before they really received consumer acceptance but since that time this type of carpet has, according to one trade journal, accounted for 65% of the total sales in plain-color carpet.

Texture floor coverings are represented by various types of rough, nubby fabrics in plain colors, or with a self-color pattern, or with a pattern in one or more contrasting colors. A change from the usual process of spinning the woolen yarns is the first

¹ Madge E. Dilts, *Carpets and Rugs*, The Hoover Co., 1943, p. 28.

² *Ibid.*, p. 30.

Factors which Determine the Quality of Carpets and Rugs



These are factors of quality which are determined by well known Technical Laboratory tests

Prepared by
A G Ashcroft, Product Engineer
In charge of
Product Engineering Dept.
Alex Smith & Sons Carpet Co., Yonkers, N.Y.
1936

step in producing texture weave. First, each single strand to be used in a texture fabric may be given 6 to 7 turns to the inch instead of the usual 1 or 2 turns. Whether or not the single strands are tightly spun, the 3-ply strand of which the pile tufts are made, will receive an additional 7 to 9 turns to the inch rather than 3 to 5 as is usual. This produces a hard, tightly curled yarn which is treated by patented processes to make it stay tightly curled as long as the carpet will wear.

Texture carpets may be woven on Wilton, Chenille, Velvet or Axminster looms. An almost infinite variety of effects may be obtained by the use of heavy and lightweight yarns, or hard-twist and soft-twist yarns in combination in the same fabric. Yarns of two or three colors may be twisted together in the same tufts. Self-tone designs, and carved and embossed effects may be obtained by using together cut and uncut pile, or high and low cut pile.

There are certain definite advantages in texture floor coverings which account for their popularity. In self-tone designs they give the same effect of a wide expanse of floor which is secured by plain color broadloom carpets of soft-twist yarns, but they have much less tendency to show soil, crushing, and foot marks. They are also less monotonous than solid-color carpets of soft-twist yarns because of the play of light and shadow upon the surface of the carpet. They repeat also the ribbed and texture effects found in modern upholstery and drapery materials and they blend well with modern furnishings. Texture rugs are also very durable because of the heavy yarns used in their construction.

The term "texture" is also applied to carpets with uniform cut pile in which there is a visual texture effect. This visual effect, in reality an optical illusion, is obtained by designs in two or more colors intended to simulate the various texture effects obtained in flat-weave fabric such as homespuns, twill and herringbone weaves, corduroys, frieze, etc.

Suggestions for the Laboratory

Compare samples of rugs. Can you recognize the various types? Is it possible to determine quality by a study of the samples?

Make a trip to a rug department and obtain information concerning the materials offered for sale. What information concerning the construction is available?

From articles and advertising material determine what information is given out by manufacturers with regard to the quality of material and the type of construction used.

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Unit Three

THE CARE OF FABRICS

A FABRIC when used inevitably becomes soiled. Careful scrutiny will reveal some soil on a bridal veil worn but once, as surely as casual attention will reveal dirt on the grimy blouse of a boy fresh from the ball game. The nature and degree of the soil might vary from the trace of dust caught in the mesh of the veil to a conglomerate hodge-podge of grass stains, candy smears, blood from a bleeding nose, and mud from the athletic field, caked on the sleeve of the blouse.

The soil on the veil may be so slight as to be almost imperceptible, and no cleaning measure may be necessary in its care. The blouse, on the other hand, may be so soiled that to safeguard the fabric as well as to secure satisfaction in the use of the garment it must be subjected to drastic cleaning methods. The use to which ordinary household and clothing fabrics are put makes cleaning necessary for most articles if they are maintained in a condition to furnish satisfaction. To a certain extent, the character of the fabric determines its ease of soiling and the resultant necessary cleaning. A napped or rough-surfaced fabric, or one made of soft yarn, tends to collect grime and soil more readily than does one of smooth surface, made of firmly twisted yarns. What other characteristics of the fabric may affect its resistance to soil? When a garment is soiled, what materials foreign to the fabric in its pure or fresh state may be present? There may be perspiration, body excretions, meat juices, blood, or egg. (See page 527.) These are commonly classed as animal stains and spots. Considered with them as completing the list of stains and spots of organic

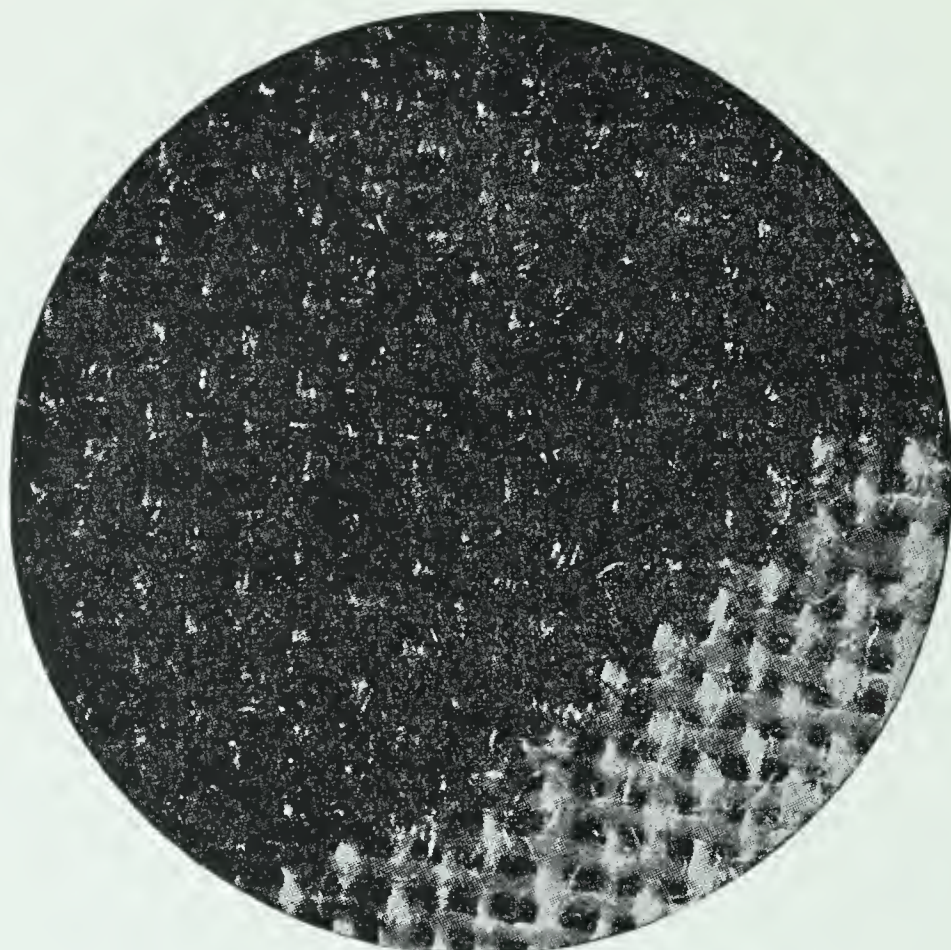


From Lydia Ray Balderston, *Laundering*, J. B. Lippincott Co., 1923

Soil produced by whole egg beaten. White forms cloudy coating; yolk penetrates, showing fat globules.

origin are the vegetable stains resulting from fruit and grass, and the food stains, such as sugar, albumin, and fat. Mud and dust head the long list of inorganic substances that soil clothing and household fabrics. In this category would be found medicine, dyes, ink, metals, and paint. (See picture page 528.)

In this list of "materials foreign to the fabric in its pure state," as soil has been defined, a wide range in chemical composition and in physical consistency will be noted. The degree or amount of soil further affects the care which fabrics need to receive. As the degree of soil is increased the problem of cleaning becomes more difficult. When considering the cleaning of any fabric, the nature of the fiber, the type of construction, and the finish will determine the procedure to be followed. Can you see why any one fabric might react differently to the various types of soil? In cleaning the fabric we have a real problem in textile chemistry.



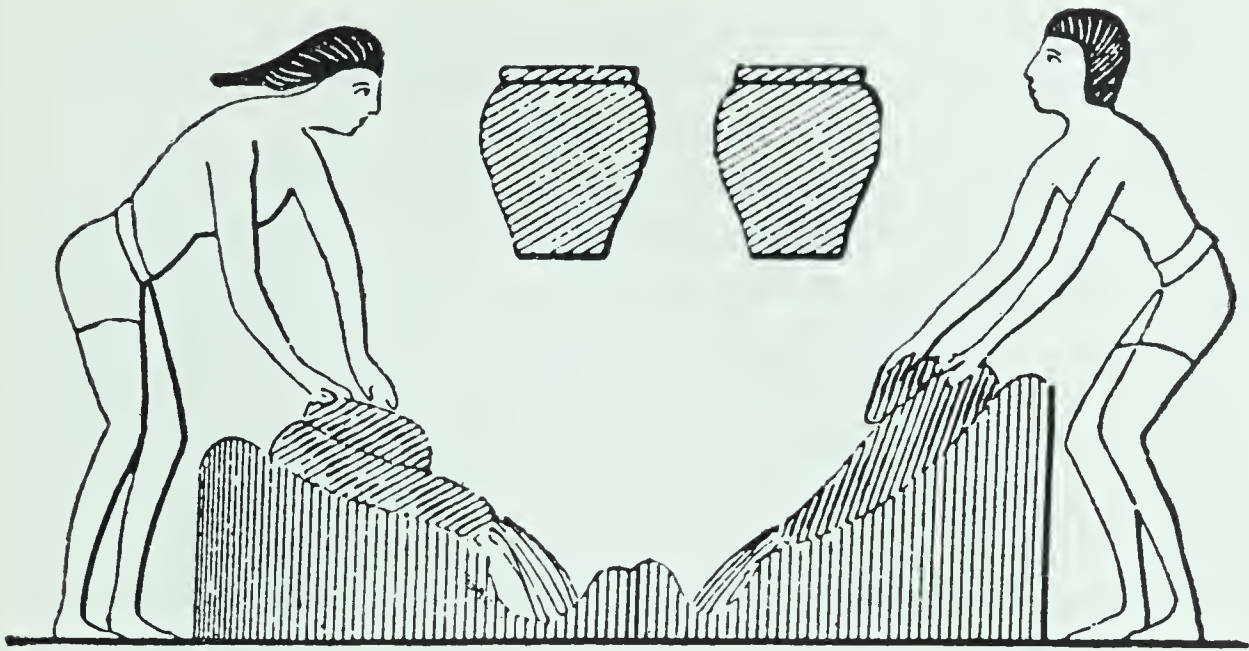
From Lydia Ray Balderston, *Laundering*, J. B. Lippincott Co., 1923

Ink acts as a dye on cotton.

The removal of soil from fabrics is usually done by one of two methods: laundering or dry cleaning. Laundering, the washing of fabrics with suds and water, is the most common method; it is inexpensive and, in the cases of fabrics and garments not injured by it, is the most effective treatment. The diversity of fabrics complicates the procedure and makes certain considerations important before deciding upon the method of cleaning.

PROBLEM 1. WHAT ARE ESSENTIAL CONSIDERATIONS IN LAUNDERING FABRICS?

Characteristics of fabrics. To be laundered satisfactorily a fabric must possess certain characteristics, and to the extent that it deviates from these, laundering becomes difficult and may be attended with only partial success or even with failure.



Washing clothes in Egypt, eighteenth century, B. C.

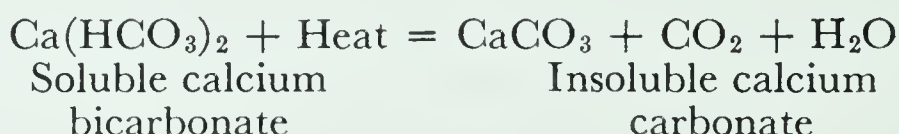
The process of laundering, as commonly used, subjects fabrics to the action of water, temperature, friction, and a detergent. If the fiber is materially weakened by water, as is the case with some rayon, then a specific problem arises. If the fabric shrinks to a marked extent under the process of laundering, as is the case with most wool and with crepes of other fibers, then a problem of another type is encountered. All fabrics that have been overstretched in finishing shrink when wet.

The method of construction of the fabric often necessitates the use of precautions and specific methods of handling to assure even partial success. For instance, knitted materials stretch easily and must be handled carefully and spread out to dry instead of being hung as other fabrics. Sheer, open-mesh woven cloth requires as careful handling as do knitted materials to prevent its being torn or pulled out of shape.

Some fabrics contain finishes that are removed by heat and suds water or they have been dyed with colors that are not fast to these agents. When there is any doubt of the effect of laundering on the color and finish, this should be determined before laundering by testing a sample of the material.

Chemically pure water. The fact that water is a good solvent makes it invaluable in cleaning fabrics. When chemi-

cally pure or approximately so, its effectiveness as a solvent is greatest. Unfortunately, water rarely reaches us in that state. Even when clear and free from suspended matter its effectiveness as a solvent causes it to carry in solution from the earth gases, organic compounds, and salts of calcium, magnesium, iron, and manganese. The presence of these substances interferes with the cleansing process. Water containing the soluble salts of the alkaline earths, especially calcium and magnesium, is designated as *hard* water. Water free from these substances is designated as *soft* water, and is most desirable for laundering purposes. In certain cases the salts that are present can be precipitated by boiling. Such water is said to be temporarily hard, and may, by the application of heat alone, become fit for laundry purposes. Temporary hardness is due to soluble alkaline bicarbonates, chiefly the bicarbonates of calcium and magnesium, held in solution by the dissolved CO_2 . Boiling drives off the CO_2 , and the soluble bicarbonates are changed to insoluble carbonates which form a precipitate.



Permanently hard water contains salts of lime and magnesium that are not precipitated by boiling.

The extent to which these salts occur in water can be found by testing it to determine its hardness. The following method will give the index to the water hardness:

Add two drops of methyl orange solution to a hundred cubic centimeters of the water to be tested. Add ten drops of $\text{N}/10$ HCL . If the water is not alkaline (soft) the color will change to red, indicating an acid condition. If the water is alkaline (hard) the color will remain yellow. To prepare methyl orange, dissolve one gram of powdered methyl orange in distilled water and dilute to one liter.

The relative hardness of water is expressed in the term "grains hardness," which means the number of grains of calcium carbonate, or its equivalent in other impurities, in one

U. S. gallon. One grain or degree as it is sometimes called is equivalent to .065 grams or .0023 ounces of calcium carbonate.

Water containing not more than four grains of hardness is regarded as soft; that exceeding twelve grains is hard.¹ In the presence of these salts soap forms an insoluble, greasy, tenacious curd of calcium or magnesium compounds which clings to fabrics in gray flecks that are difficult to remove and, being insoluble, are inactive in cleansing. Before a lather or suds can be produced in hard water the lime and magnesium compounds must be decomposed. If this is done with soap, it is found that each grain of calcium carbonate will use up eight grains of soap (dry weight) before a lather can be produced.² Upon this basis every hundred gallons of hard water used in laundering would destroy at least two pounds of soap (dry weight), or three pounds (as purchased) before the water would be freed from the salts of the alkaline earths so a suds could be formed.

Water softeners. When permanently hard water must be used for laundry purposes it is necessary to use a softener that will precipitate these salts of the alkaline earth. The softeners commonly used in homes are washing soda, borax, and trisodium phosphate preparations, all of them being much cheaper than soap and several times more effective per given weight. Can you explain why?

In the use of any of these substances insoluble crystalline calcium or magnesium compounds are formed, which sink to the bottom of the liquid. In ordinary household procedures, this reaction is rarely complete in less than fifteen minutes. Obviously the "breaking" of water should be done without leaving an excess of the softener in it. Housewives learn by experience the degree of hardness of the local water supply. In cities where the water is to be softened, titration as suggested is used to determine the quantity of softener to be added per gallon of water. What quantities are suggested for

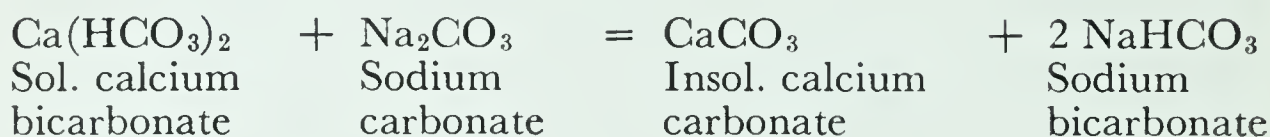
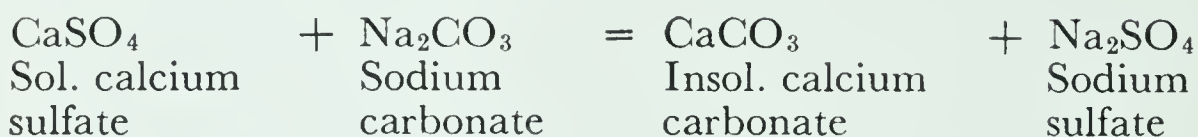
¹ M. J. Rosenau, *Preventive Medicine and Hygiene*, p. 1062. D. Appleton-Century Co., New York, 1922.

² *Ibid.*, p. 1061.

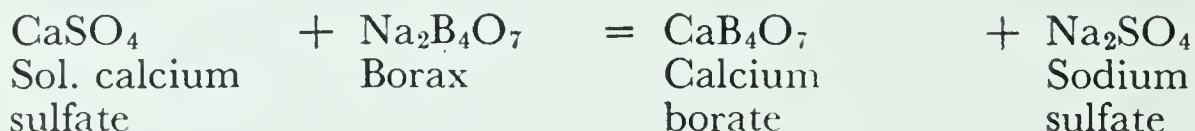
use on packages of various common commercial water softeners?

The chemical reactions by which the softening is done are as follows: ¹

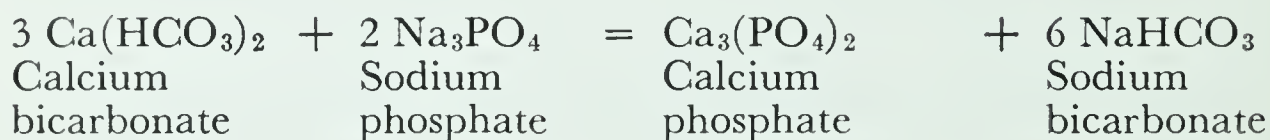
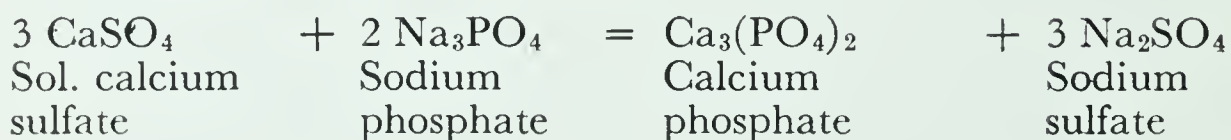
Washing soda as softener:



Borax as softener:



Trisodium phosphate as softener:



Not infrequently cities or towns assume the responsibility of providing water that is both safe from disease-bearing organisms and soft enough for economical use in household activities. In such cases the softeners are usually combinations, carefully computed, of slaked lime, washing soda, and calcium hydroxide. In certain such cities studies have been made showing the marked saving to the housewives in the reduction of commercial softeners purchased.

In other cities the so-called zeolite water softening process is used, though it is more commonly found in the commercial

¹ From Ellen B. McGowan, *A Comparative Study of Detergents*, pp. 30, 31. Bureau of Publications, Teachers College, Columbia University, New York, 1930.

laundries and in textile mills. The basis of this method is a synthetic exchange silicate which is made by fusing feldspar, kaolin, pearl ash, and soda. The passage of water through this material softens it by freeing it from the calcium and magnesium, these being replaced by the sodium from the filter. The depleted sodium can be restored in the filter by treatment with 10 per cent sodium chloride.¹

Frequently water contains iron in solution or suspension. Though this may result from the solution of iron by the carbon dioxide charged water in its natural state, it is found that more frequently the water mains, or the hot water tanks in the home, are responsible. Failure to secure water free from iron through attention to these points not only makes laundry processes more difficult but may also weaken fabrics.

One of the greatest difficulties encountered in the use of soap in hard water is the formation of insoluble lime soaps. When this happens the detergent power of the soap is destroyed and the lime soap is deposited on the clothes. This objectional feature of soap is overcome by adding a substance that will neutralize this tendency. Sodium hexametaphosphate or "Calgon" is an example of a compound which will successfully prevent the formation of lime soaps. The use of this type of water softener permits washing in hard water without precipitation of lime soaps and with no loss of the cleaning power of the soap used.

Soap. Why is soap often used to aid the removal of most types of soil? What kinds of soap are effective? In ancient times when the washing was done on the river bank it was found that certain types of clay helped to remove soils that resisted the action of water. There exists a resistance or repellence between dirt and water which these substances tended to break down. That is, they reduced the surface tension of the water and permitted the soil or dirt to form a solution or suspension in water, thus facilitating its removal. Even today, in some lands, certain clays serve instead of soap for the poorer people. Though soap in some form has been used in

¹ M. J. Rosenau, *op. cit.*, p. 1063.



Courtesy F. S. Lincoln

Primitive methods of laundering, often back breaking, still prevail in many parts of the world.

cleansing processes for more than twenty centuries, it has come into common use only during the last five centuries.

Our ancestors combined wood ashes and animal fats to make soaps which they used to secure the removal of dirt. Fats and oils, whether of animal or vegetable origin, are esters of the fatty acids. When hydrolyzed or saponified in the pres-

ence of a base, a mixture of the corresponding salts of the base is obtained. These mixtures are known as soap, the production of one form being expressed in the following equation:



Sodium hydroxide and potassium hydroxide either alone or together are used in the production of the ordinary soaps. Soaps differ in the fat from which they are made, the alkali chosen, the amount of free alkali they contain, and the percentage of foreign matter and water present. They are said to be hard or soft, depending upon their melting point. This difference is due to the variation of the fat or fats and the alkali used in their preparation.

The hard fats are largely of animal origin, except for an increasing quantity of hydrogenated vegetable oils that have been changed into a chemical composition similar to the hard animal fats by the introduction of hydrogen. Bar soaps prepared for laundry use are commonly made from hard fats treated with sodium hydroxide.

Soft soaps are usually made from an oil treated with potassium hydroxide.

When dissolved in water, soap tends to hydrolyze—that is, split up into free alkali and fatty acids. This action proceeds until there is an excess of alkali which hinders further hydrolysis. The undecomposed soap is the only active part of the solution and is indicated by a suds.

Laboratory tests of many popular types of soaps found on the market showed no free alkali present in any of the dry soaps. These soaps in water solutions indicated marked differences in the amount of free alkali present in the suds; but every type of soap tested when in solution gave indications of the presence of alkali. The amount of free alkali in soap suds due to the hydrolysis of the soap is constant for a specific type and is dependent largely upon the oil or fat employed in its manufacture and in the temperature of the suds. Free alkali added to the soap or soap solution prevents hydrolysis, thus increasing the amount of soap available as detergent. Soaps free from alkali, therefore, are not so effective cleansers as are

alkali soaps. Soaps or bleaches that are strong enough to remove dirt simply by soaking will injure many fabrics and colors. The selection of the proper soap is determined by the specific case—by the type of fabric, including the kind of fiber used, and by an understanding of the factors involved in the cleansing action of soap.

The cleansing power of soap depends in part upon its ability to reduce the interfacial tension between the water and the soil. Suds, which are the result of the enclosure of tiny bubbles of air each surrounded by a soapy film, are produced. The action of the soap in this emulsion is considered to be the result of the presence of colloidal particles in solution. In a colloidal solution the ultra-microscopic particles are in constant motion. This solution is said to have a greater attraction for the particles of dirt than is exerted by the fiber, and so soil is adsorbed to the soap in its colloidal form. Between the bombardment of the constant motion of the particles and the process of adsorption, cleansing is accomplished. Too large a quantity of soap has been found to retard the detergent action.

Detergency is the act of cleansing, and, as has been explained above, this action is due to the ability of the soap suds to wet the fabric and draw the soil away from it. The particles of dirt are held in suspension in the soap suds and are removed with it. If clothes are very soiled it will require two or more suds to remove all of the dirt present. A sufficient number of rinse waters must be used to remove thoroughly all traces of soap. The temperature of the suds must be maintained in the rinse waters to prevent coagulating the soap in the fabric rather than removing it.

Soap may be secured on the market as bar soap, flake soap, soap in grains or beads, and as powdered soap. Certain well-known soaps are produced in all four types, the difference in such a case being largely one of mechanical subdivision and moisture content, though vegetable oils may be more commonly used in the flakes.

Bar soap may contain 30 to 35 per cent moisture, whereas flake soap of the same brand may contain only 5 per cent. The

temperature at which the soap suds should be maintained during the laundry process has a close relationship with the type of soap used, as well as with the fabric to be washed, and the nature of the soil.

Moderate temperature of 100° F., which is only slightly higher than that of body heat, has been shown to be within the range of effective sudsing of the vegetable-oil soaps, and to be safe for the washing of wool, silk, and synthetic fiber fabrics, and safe for dyes that might be adversely affected by high temperatures. Ordinary laundry soaps may require a temperature of 160° F. for effective sudsing. In the usual laundry procedure there seems no need for raising the temperature above 160° F. The custom of boiling makes no contribution to the cleansing process, causes deterioration of fabrics, and seems unnecessary as a sterilization measure under normal home conditions.

Although soap is the most commonly used type of detergent, synthetic compounds for use in laundering are available. These are the result of extensive research. Some of the synthetic detergents are sulfated products in which the COOH group has been reduced to a CH_2OH group. These fatty alcohols do not break down or hydrolyze into a fatty acid and alkali in water. Hence, with this type of detergent a neutral bath may be maintained. These compounds have excellent detergent properties. In another type of synthetic detergent the COOH group has been "blocked," through esterification or other means. Many commercial products of this type are now being produced for use in the industries and also in the home.

Washing machines. Even with soap and proper temperature mechanical agitation is required to remove dirt in laundering. To secure this action there are various types of washing machines on the market. In general the effectiveness of their action under given conditions is based upon (1) the degree of agitation maintained, (2) the type of agitation maintained, and (3) the quantity of sudsing solution employed per pound of clothes.

The study of the comparative effectiveness of various types

of washing machines belongs logically to the field of household equipment. However, to safeguard fabrics it is important to know that excessive suction should not be used, that the equipment should tend to force water through the clothes instead of the clothes through the water, and that tangling, knotting, and twisting should be avoided.

Laundering rules. When laundering any articles, whether few or many, in the home or in the commercial laundry, there are certain rules to be observed. Clothes of a similar nature should be grouped together; sufficient water of comparative softness must be prepared; soap of the correct type should be available; proper temperatures should be maintained; and the equipment must be clean. The iron should be maintained at a temperature suitable for the fiber content of the fabric.

Ironing temperatures for fabrics of different fiber content follow: ¹

Rayon-low and nylon	300° to 350° F.
Rayon-high and silk	350° to 400° F.
Light and starched cotton	400° to 450° F.
Wool pressing	450° to 550° F.
Heavy cottons and linens	500° to 550° F.

All stains not readily removed by soap and water should be removed before laundering, the specific procedure and remover being determined by the type of stain and the nature of the fabric. Exceptionally dirty pieces of white clothing may be soaked in cool to lukewarm suds. To clean fabrics successfully by laundering, sufficient suds to dissolve and remove the dirt must be used. This may in some cases require more than one suds water. In most instances it is better to use liquid soap or to dissolve the soap in the water before adding the clothes. The temperature of the water will be determined by the fabric to be cleaned. After the clothes are clean, they should be rinsed thoroughly to remove the soap. Soap remaining in the clothes causes yellowing, especially when ironed with a hot iron.

¹ Post War Ironing Temperatures. Good Housekeeping Institute.

Because alkali injures wool fibers, it is necessary to use a neutral soap or a synthetic detergent in the laundering of wool fabrics. One needs to keep constantly in mind the result, of heat, moisture, and friction on the felting properties of wool fibers. Wool fabrics should be washed in soft, lukewarm water with as little friction as possible. All water should be kept at nearly the same temperature (about 100° F.). It has been proved that a change in temperature of the water and the drying atmosphere has as great an injurious effect as does moderately strong alkali soap. Wool should be hung neither in the hot sun nor in freezing temperature. If the above precautions are observed, laundered wool fabrics will shrink but slightly and will remain soft and pliable. Poorly or carelessly laundered wool fabrics will be harsh and thick and severely shrunken.

A "blanket wash" is sometimes used in the place of soap for washing blankets:

Dissolve one large bar of mild white soap in three quarts of hot water. When thoroughly dissolved and somewhat cooled, add one cup wood alcohol and two tablespoonsful of borax. Use sufficient of this blanket wash to make a good suds.

If the blankets are extremely soiled the following detergent will assist in the cleaning:

Detergent: 1½ oz. castile soap dissolved in 1 pint of hot water. Add 3 quarts water, 1 oz. wood alcohol, 1 oz. ether, 4 oz. ammonia. Stir vigorously.

Wool should be dried where the air is circulating freely and where it is not extremely cold or hot. As wool absorbs a large amount of water and becomes weaker when wet, no part of the blanket should be required to bear a great weight.

The hanging of blankets and other large wool articles on two lines a few feet apart or even on three lines is recommended. This plan permits the weight to be well distributed and the fabric to dry rapidly. The ready access of the air to both sides of the blanket tends to fluff up the nap, which makes the blanket softer and warmer.

The same precautions are necessary for the successful laundering of silk. Silk, however, is slightly less sensitive to the action of alkalies and heat than is wool, and friction does not have the same disastrous result.

White wool and white silk tend to become yellow as the result of oxidation, which is greater in the presence of moisture and light. Drying in the dark will prevent excessive yellowing. Most silk fabrics should be rolled in a soft towel in such a manner as to prevent the fabric from being in direct contact with itself; that is, spread the fabric flat on the towel and roll. Silk should be ironed when only partly dry. This is not true of pongee, which should be dried thoroughly and ironed when dry. A hot iron should not be used directly on either silk or wool fabrics. With wool especially, it is best to use a pressing cloth and a moderately hot iron. A steam iron is highly recommended for use with wool.

The laundering of rayons presents a specific problem for each type, owing to the different effect of moisture on each. These fibers are alike in that they all have a smooth surface which makes them resistant to soil and easily cleaned. Soft water and any mild detergent will clean these fabrics thoroughly. Warm water, comfortable to the hands, should be used, and two suds should be used if necessary. All suds should be completely removed. As most rayons are weakened by water, they should not be rubbed or twisted but should be gently squeezed between the hands.

Cellulose acetate fabrics should be dried in a towel and ironed with a warm, not hot, iron. As high temperatures melt this type of material, and ironing when wet causes a lustering of the fabric, care should be taken to prevent the formation of wrinkles during washing or drying. Whenever possible, garments of cellulose acetate fabric should be ironed on the wrong side. This is especially true when pressing plaits.

Bemberg fabrics may be handled as silk, washed in lukewarm water, wrapped in a towel for a short time, and ironed.

Viscose and nitrocellulose fibers are more affected by moisture than the other two and must receive more careful handling. These fibers should not be required to bear their own

weight when wet; they should be spread out to dry instead of being hung as other fabrics, and should be ironed when dry.

Nylon presents few problems with regard to laundering. It absorbs little moisture and retains its dry strength. Soil is removed from nylon more easily than from most fabrics, so it is unnecessary to use a strong detergent or a high temperature in washing; and since wrinkles are removed easily, a cool iron is satisfactory for ironing or pressing.

Aralac possesses about 60 per cent of the strength of wool when dry, and it becomes weak and stretches badly when wet. It has less resistance to alkalies than wool. For these reasons, great care should be used if Aralac is washed. In most instances, dry cleaning is recommended rather than washing. It is important that fabrics containing Aralac be dried thoroughly because this fiber mildews easily and develops a disagreeable odor if allowed to remain wet for any length of time. In ironing or pressing, Aralac can be handled the same as wool.

Vinyon is being used in combination with other fibers in necktie fabrics. Great care should be used in pressing this material since it melts at low temperatures. Vinyon begins to shrink at slightly above 149° F., which is below the temperature of steam or of the average iron.

The use of many different resins and other compounds in the development of new finishes such as water-repellency and crease and wrinkle resistance has increased laundering and pressing problems. No general rules can be given since each finish presents a special problem. Whenever possible, a sample from an unexposed part of the material should be tested before the entire fabric is cleaned.

Both cotton and linen fabrics, with few exceptions, are cleaned by laundering. Moisture increases the elasticity and breaking strength of these fibers. The action of sunshine tends to whiten them and they can withstand high temperatures without injury. Though both are resistant to the effect of alkalies, linen is slightly more sensitive, and therefore such agents should be used in moderation on this fiber.

It is wise to hang colored fabrics of all kinds in the shade.

where there will be sufficient circulation of air to dry them quickly, as such fabrics dried slowly tend to streak, and when exposed to the rays of the sun are more likely to fade.

Stain removal. Stain removal is of daily importance. Success in the removal of stains often depends upon immediate action. All stains are removed more easily when fresh and fabrics should not be washed or dry cleaned before the stains have been removed as soap and water and a hot iron set many stains. The type of fiber and the type of stain determine the remover that it is safe to use and the method of its application. The three ways most commonly cited as means of stain removal are by absorbing, by dissolving and by bleaching. Absorbents commonly used are fullers' earth, French chalk, starch, and meal. If the absorbent is applied to a spot and allowed to remain there for several hours, some of the grease or substance causing the spot may adhere to the absorbent used. On brushing it from the fabric, a second treatment may be found necessary. The spot may grow less conspicuous, but complete removal is seldom possible through use of absorbents.

Removal of the stain by dissolving it is, of course, the preferred method. Common solvents are water, alcohol, benzine, carbon tetrachloride, ether, gasoline, and turpentine. Before applying a solvent to colored material, first test its effect on the dye on an unexposed part of the article. The application of the solvent should be made under those conditions that will assure its greatest effectiveness. If cold water is used as the solvent the stained material is soaked and later washed. If boiling water is used as the solvent, the manipulation should be such as to secure the flow of boiling water through the spot.

When the water would be harmful the solvents used, as carbon tetrachloride, ether, benzine, and gasoline, are usually applied sparingly. The stained material is stretched over a pad and the application is made from the edge to the center. The pad needs frequent changing.

Bleaches are termed stain removers, but in reality they merely remove the color from the stain so that the substance,

though not removed, is invisible. Bleaches are used chiefly on white material, most commonly on linen and cotton. Familiar agents used on white goods are lemon juice, sour milk, hydrogen peroxide, sodium perborate, Javelle water, oxalic acid, sodium hydrosulfite, and sunshine. Of this list, only hydrogen peroxide, sodium perborate, and sunshine may be used with safety on wool and silk. Whenever Javelle water is used, it should be slightly acidified first, then followed with a rinse and a treatment with bisulfide of soda to remove the chlorine, after which a second rinse is given.

A suggested procedure in the case of unidentified stain is as follows: If the fabric will not be injured by water, apply cold water. If this fails, try warm water. If this does not give satisfactory results or if the fabric cannot be treated with water, try those substances that are fat solvents.

The following directions for the removal of some of the more common stains were taken from the revised edition of "Stain Removal from Fabrics," Farmers' Bulletin, No. 1474, U. S. Department of Agriculture.

Alcoholic beverages and soft drinks. Alcoholic beverages and soft drinks may cause tannin stains. Fresh tannin stains are almost colorless, but if they are allowed to stand or are washed in soap and water or heated as in ironing and pressing, they turn brown and are almost impossible to remove. Fresh stains can be removed as follows:

Cold water and glycerine. Sponge the stain with water or with a mixture of equal parts alcohol and water. Then pour glycerine on the stain and rub between the hands. Let stand for a half hour and rinse with water.

Acetic acid. If the above treatment does not remove the stain, apply a 10 per cent solution of acetic acid with a medicine dropper and let stand a few seconds. Rinse and repeat if necessary. Stop the action of the acid with baking soda or ammonia and spread the garment in the sun.

Bleaches. The last traces of stains on white materials can sometimes be removed by bleaching. Use one of the following:

Hydrogen peroxide or sodium perborate. Sponge lightly with hydrogen peroxide or with a mixture of 1 level teaspoon sodium

perborate to 1 pint hydrogen peroxide. If this does not remove stain, cover dampened spot with powdered sodium perborate and let stand an hour. Rinse in water.

Javelle water. For stains on uncolored cotton or linen material, dip in Javelle water for 1 minute (no longer), remove the chlorine from the cloth with a sodium thiosulfate solution, rinse well in water. Do not use Javelle water to remove stains from colored materials or from silk or wool.

To prepare Javelle water: Mix $\frac{1}{2}$ pound washing soda in 1 quart of cold water. Add $\frac{1}{4}$ pound of bleaching powder (commonly called chloride of lime). Strain this liquid through a piece of muslin and store in a bottle with a tight cork or stopper ready for use.

To remove a stain with Javelle water, stretch the stained part of the cloth over a bowl filled with cold water and drop the Javelle water on the stain with a medicine dropper. (If the stain is large, dip the entire garment in the Javelle water.) Never let the Javelle water remain on the stain for more than 1 minute; it rots even linen and cotton materials if allowed to remain on them longer. Rinse quickly by dipping in water.

Next, apply a few drops of a solution made up of $\frac{1}{2}$ teaspoon of sodium thiosulfate and 1 to 2 teaspoons of vinegar in 1 pint of water. This stops the action of the chlorine remaining in the cloth after the treatment with Javelle water. Then rinse the cloth well in clear water. You may use vinegar alone or oxalic acid solution (1 teaspoon oxalic acid to 1 pint water) instead of the thiosulfate solution, but they are not so satisfactory. To remove the stain completely, you may have to repeat the Javelle water-thiosulfate treatment several times.

Sodium perborate is one of the safest bleaches for all types of materials. The treatment must be rapid and the sodium perborate well rinsed from the material, however, or it will take out the color. It will not remove some ink stains, iron rust, dyes and running color, or metal stains.

For small, fresh stains, sponge with a liquid made up of 4 tablespoons sodium perborate to 1 pint lukewarm water. Or stretch the stained cloth over a bowl of hot water, dampen the stain with water, and dust the powdered sodium perborate on it. Let stand a minute or two; then sponge or rinse well with water.

For a large stain, soak the entire garment for a half hour or longer in sodium perborate and soapsuds (4 tablespoons perborate

to a pint of soapy water). To remove grass, beverage, mud, scorch, and some perfume stains, mix 1 level teaspoon sodium perborate with 1 pint hydrogen peroxide. But use this mixture immediately, as it soon loses its strength. Rinse in water.

Sodium perborate is particularly good to use on white woolens; it leaves them soft and fluffy.

Hydrogen peroxide, obtained at drug stores, is a good bleach for light scorch stains. The action of hydrogen peroxide is quicker if a few drops of ammonia water are added to it just before use. Or you can add 1 level teaspoon of either borax or sodium perborate to 1 pint of peroxide. Apply it to the stain with a medicine dropper or a glass rod, or sponge the stain with it. Follow by careful sponging or rinsing with water.

Blood. Blood stains will usually come out if sponged or washed in cold or lukewarm water first. Never use hot water; it sets the stain.

Cold or lukewarm water. For stains on silk or wool, sponge with cold or lukewarm water. For washable material, soak the stains in cold water until they turn light brown in color; then wash in warm soapy water. If the stain is an old one and has dried, it may help to add 2 tablespoons of ammonia water to each gallon of water used for soaking. Strong salt water (about 2 cups of salt to 1 gallon water) is also good to loosen the stain.

Hydrogen peroxide and sodium perborate. If the above treatment does not completely remove the stain, sponge with hydrogen peroxide. Or sponge with a mixture of 1 level teaspoon sodium perborate to 1 pint hydrogen peroxide. If the stain still shows, cover the dampened spot with powdered sodium perborate and let stand an hour. Rinse thoroughly. These bleaches will not harm the cloth, but before using test for colorfastness on a sample of cloth or on an inner seam of the garment. If the color fades, do not use the bleaches; just dampen the stain and spread in the sun to bleach.

Starch. Use a starch paste to remove stains on thick materials, such as flannel and blankets, which cannot be soaked in water. Mix raw starch to a paste with cold water, apply the paste thickly to the stain, and brush it away when it dries. Repeat the treatment until the stain disappears.

Candle wax, colored. Scrape away as much wax as possible with a dull knife. Then treat as follows:

Blotting paper. Place the stain between clean white blotters,

cleansing tissues, or paper towels, and press with a warm iron, changing the blotters as they become soiled. Then sponge with carbon tetrachloride or other grease solvent.

Denatured alcohol. If a color stain remains, sponge with liquid made up of 1 cup denatured alcohol and 2 cups water.

Candy. Launder in warm soapy water if the material is washable. Otherwise, sponge with clear warm water.

If dye or chocolate stains remain, follow instructions given under Chocolate and Cocoa.

Chewing gum. Use one of the following methods:

Ice. If the material will not water-spot, rub the gum stain with ice. Then scrape and rub the hardened gum out of the cloth. This method is particularly good for rugs and other heavy materials.

Egg white. If the material is washable, soften the gum stain with egg white and then wash.

Carbon tetrachloride, kerosene, or turpentine. Soak the stain in carbon tetrachloride, kerosene, or turpentine. If kerosene is used, wash in warm soapy water afterwards.

Chocolate and cocoa. It may be necessary to try more than one method to remove chocolate and cocoa stains, since they usually contain other substances such as fat, milk, starch, and sugar. First scrape off as much of the stain as possible with a dull knife; then try one of the following:

Soap and warm water. If the material is washable the regular laundering in warm soapy water will often remove this stain.

Hydrogen peroxide and sodium perborate. Sponge stubborn stains with hydrogen peroxide. Or use a mixture of 1 level teaspoon sodium perborate to 1 pint hydrogen peroxide. If the stain still shows, cover the dampened spot with powdered sodium perborate and let stand an hour. Rinse thoroughly. Be sure to test for color change on a sample of the cloth or on the inside of hem or seam of the garment before using these bleaches on the stain.

Carbon tetrachloride and pepsin. If the cloth is not washable sponge with carbon tetrachloride to dissolve the grease. Dry thoroughly, then sponge with warm water, and dust with pepsin powder. Work the powder into the cloth, let stand for 30 minutes or longer, then sponge with water.

Coffee and tea. For the removal of stains made by coffee and tea there are three methods.

Water and glycerine. If the stains are on wool or silk, sponge

with lukewarm water. Then apply glycerine and rub lightly between the hands. Let stand for half an hour and rinse thoroughly with water. If a grease spot from cream remains, sponge with carbon tetrachloride.

Boiling water. Remove fresh stains from washable materials by pouring boiling water on the stain from a height of 2 or 3 feet, then wash in warm soapy water. If a trace of stain remains, dry in the sun or bleach with hydrogen peroxide and sodium perborate.

Hydrogen peroxide and sodium perborate. Sponge with clear water and then with a solution of 1 teaspoon sodium perborate to 1 pint hydrogen peroxide. If the stain still shows, sprinkle powdered sodium perborate on the stain and let stand half an hour. Rinse well with water.

Egg. Scrape away as much of the stain as possible with a blunt knife. Then sponge with cold water. Never use hot water—heat makes egg stains harder to remove.

Pepsin. If cold water does not remove the stain completely, sprinkle pepsin powder over the spot. Work it in well and let stand for half an hour. Rinse well.

Fingernail polish. For the removal of fingernail polish, these following methods are suggested.

Acetone or nail-polish removers. On any material except acetate rayon or vinyon, sponge the stain with acetone or a commercial nail-polish remover.

Grease solvent and banana oil (amyl acetate). Use this treatment on any material including acetate rayon and vinyon. First wet the stain well with carbon tetrachloride or gasoline; then apply a drop of banana oil to the stain. Brush lightly with a soft cloth, using an upward motion to pick up the dissolved polish. For heavy stains use dry-cleaning soap with the banana oil.

Bleaches. To remove any color remaining after the polish itself has been dissolved, apply a bleach. Test the cloth for change in color first.

Hydrogen peroxide and sodium perborate. Sponge with clear water and then with a solution of 1 teaspoon sodium perborate to 1 pint hydrogen peroxide. If the stain still shows, sprinkle powdered sodium perborate on the stain and let stand half an hour. Rinse well with clear water.

Hydrosulfite. Apply one of the hydrosulfites available at drug stores as a color remover. Follow directions on the package.

Fruits and berries. Treat fruit and berry stains immediately, if

possible; they are hard to remove after they dry. Boiling water (if it does not harm the cloth) or sometimes even warm water will remove most fruit stains. It is better not to use soap, as alkalis set some fruit and berry stains. Use the same methods for removing stains from cooked fruits and berries as from fresh.

Washing in warm soapy water sometimes removes stains from citrus fruits, such as grapefruit and lemon. But if the stain is old or the cloth has been pressed before washing, use one of the bleaches described below. If the acid in citrus fruit changes the color of the cloth, restore it with ammonia water or baking soda. (See further discussion on page 543.)

Cold water and glycerine. For fresh peach, pear, cherry, and plum stains on cotton and linen and for any fruit stain on wool or silk materials (either white or colored), first sponge the stain well with cool water; then work glycerine or a soapless shampoo into the stain, rubbing lightly between the hands. Do not use soap, as soap sets the stain. Let stand several hours, then apply a few drops of vinegar or oxalic acid, allow to remain for a minute or two, then rinse thoroughly in water.

Boiling water. Boiling water removes from cotton and linen most fruit stains except peach, pear, plum, cherry. Never use boiling water on silk or wool. Stretch the stained part over a bowl, fasten it with string, and pour boiling water on it from a tea-kettle held at a height of 3 or 4 feet so that the water strikes the stain with force. Rubbing alternated with the boiling water is also helpful. If a stain remains, squeeze a little lemon juice on it and place in the sun to dry, or use one of the chemical bleaches.

Bleaches. If a stain remains, try one of the following:

Hydrogen peroxide and sodium perborate. Sponge with hydrogen peroxide-sodium perborate mixture (1 teaspoon sodium perborate to 1 pint peroxide). Rinse thoroughly. If the stain persists, sprinkle powdered sodium perborate on the dampened area and let stand for half an hour. Finally rinse well. Always test for change of color on the inside of a hem or seam before using these bleaches. If the color fades, do not use them—just dampen the stain with water and spread in the sun to bleach.

Hydrosulfite. Hydrosulfites available at drug stores as dye removers are satisfactory for removing fruit stains from any white material. Follow directions on package.

Javelle water. For stains on uncolored linen or cotton material, dip in Javelle water for 1 minute (no longer), remove the chlorine

from the cloth with a sodium thiosulfate solution, rinse well in water. (See p. 544 for more detailed instructions.) Do not use Javelle water on silk or wool.

Grass and other fresh garden foliage. For the removal of the stains made by grass and other fresh garden foliage, the following methods are suggested.

Hot water and soap. If the material is washable, use hot water and soap, rubbing the stain well. If this does not completely remove the stain, use a bleach.

Bleaches. Try one of the following:

Javelle water. For stains on uncolored linen, cotton, or rayon, dip in Javelle water for 1 minute (no longer), remove the chlorine from the cloth with a sodium thiosulfate solution, rinse well in water. (See p. 546 for more detailed instructions.) Do not use Javelle water to remove stains from silk or wool.

Grease and oils. Fresh grease spots usually are the pure fat or oil. Old grease spots or stains from automobile, wheel, or machine greases usually contain also more or less dust, dirt, or fine bits of metal. First scrape or wipe off as much of the grease as possible; then treat the stain by one of the following methods:

Soap and water. If the material is washable, wash in warm sudsy water. Be sure to use plenty of soap on the stained part and rub well between the hands. The soaplike washing agents (soapless shampoos, oils, and lathers) are good to soften grease stains.

Absorbents. Use cornstarch, French chalk, or white talcum powder for fine materials; corn meal or salt for carpets, rugs, and other coarse materials. Dust the powder or salt over the spot, let stand until it absorbs the grease or oil, then brush off. Another method is to place the stained part between blotting papers and press lightly with a warm iron. Change the blotting paper as it becomes soiled. Or use cleansing tissues or paper towels in the same way. The advantage of using absorbents is that they do not wet the material or leave rings as water or grease solvents are apt to do.

Grease solvents. Remove common grease and oils with carbon tetrachloride, gasoline, or benzene. Place a pad of clean cloth or a white blotter beneath the stain and sponge with a clean cloth, moistened with the grease solvent. Work from the wrong side of the material in order to push the dirt and grease out rather than to rub it into the material. Use light, brushing motions, work from the outside of the spot toward the center and spread or

“feather out” the solvent into the cloth around the stain until there is no definite edge. Then pat dry with a clean, dry cloth.

If the grease spot contains dirt or fine bits of metal, first loosen the stain by rubbing a little lard, vaseline, or dry-cleaning soap into it. Then sponge with the grease solvent or dip the stain into a small bowl of the solvent.

Another method is to make a paste by mixing cornstarch or talcum with carbon tetrachloride or other dry-cleaning fluid. Spread the paste over the spot; when dry brush it off. Repeat if necessary. The solvent does not spread and is less likely to form a ring if used in this way.

Ice cream. Ice cream stains contain milk or cream, sugar, sometimes egg, and often coloring. If after trying the following methods, a fruit or chocolate stain remains, follow instructions under Fruits and Berries, page 547, or under Chocolate and Cocoa, page 546.

Cold or lukewarm water. If the material is washable and the stain contains no highly colored fruit or chocolate, sponge with cold or lukewarm water; then wash in warm soapsuds.

Carbon tetrachloride. For nonwashable materials, sponge with carbon tetrachloride to remove the greasy part of the stain. Let it dry; then sponge with cold water to remove any stains from the egg and sugar in the ice cream. If this does not remove the stain completely, follow with a pepsin treatment.

Pepsin. First sponge the stain with cold water, then sprinkle pepsin on the dampened stain, and let it stand half an hour. Brush it off and rinse the spot well. For best results, be sure the material is free from soap or other alkali before applying the pepsin.

Ink. Because inks differ in composition, it is impossible to find removers that are equally effective for all types of ink spots. Each of the methods mentioned below is satisfactory with some type of ink. For most ink spots, it is necessary to try several methods, beginning always with the simplest and that least likely to harm the cloth.

India or drawing ink. For the removal of India or drawing ink these methods are suggested.

Denatured alcohol, carbon tetrachloride, and benzene. Place a pad of cloth or blotter under the stain and sponge with one of these solvents. Then rub glycerine (use glycerine only with alcohol) or a dry-cleaning soap into the stain and finally rinse out

with the solvent. If this does not remove the stain, let the stain dry; then wet with water and rub in some soapless shampoo or soapless lather (soaplike washing agent) to help soften the stain. Or use strong soapsuds to which a few drops of ammonia water have been added. Alcohol must not be used on acetate rayon or colored materials.

Writing ink. In removing writing-ink stains it usually is necessary to try various methods. Always start with the simplest method and the one least likely to harm the cloth.

Absorbents. If the stain is still wet, spread corn meal, salt, French chalk, cornstarch, or talcum powder on the stain to remove any excess ink and to keep it from spreading. Work the powder into the stain. Shake it off as it becomes soiled and repeat the process. When the dry absorbent fails to take up more ink, make the absorbent into a paste with water or with a mixture of 1 part water and 1 part alcohol and apply again. Let dry and brush off.

Glycerine and water or soap and water. If the material is washable, pour either glycerine or one of the soapless shampoos on the fresh stain. Rub lightly between the hands, rinse, and apply glycerine again as long as any ink comes from the stain. Rinse with clear water. Washing with soap and warm water will remove some types of ink.

Bleaches. If the above treatments do not remove the stain, try a bleach. But use bleaches sparingly on colored materials.

Oxalic acid. Soak the stain for a few seconds in a solution of oxalic acid (3 tablespoons of the crystals of the acid to a pint of water). Or sponge the stain well with cold water, then stretch the stain over a bowl of hot water, and apply crystals of oxalic acid directly to the stain. Rinse by dipping in the hot water and finally in water to which a few drops of ammonia water have been added. Do not use on weighted silk.

Hydrosulfite. Sponge with a hydrosulfite solution and rinse quickly.

Iodine. For the removal of iodine these methods are suggested.

Soap and water. If the material is washable, soap and water will often remove a fresh stain. Or moisten with water and place either in the sun, over a warm radiator, or hold in the steam from a boiling teakettle.

Denatured alcohol. On materials that water would injure, sponge with alcohol. On acetate rayon and colored materials be

sure to dilute the alcohol—1 cup denatured alcohol to 2 cups water.

Sodium thiosulfate (“hypo”). Sponge the stain or dip in a solution of 1 tablespoon of the “hypo” to 1 pint of water. Rinse well in water.

Iron rust. Use any of the methods given below to remove iron-rust stains from white materials. Test remover on sample of cloth before using on colored materials.

Lemon juice. Spread the stain over a pan of boiling water and then squeeze lemon juice on it. After a few minutes rinse; then repeat the process. This method is rather slow, but does not harm delicate white cottons or linens. Another method is to sprinkle the stain with salt, squeeze lemon juice on it, and spread in the sun to dry. Add more lemon juice if the stain still shows. Rinse well.

Oxalic acid. Spread the stained article over a bowl of hot water and apply a few drops of oxalic acid solution (3 tablespoons of the crystals to 1 pint of water). Or put the crystals of acid directly on the stain and moisten with hot water. Rinse in hot water, and repeat until the stain disappears. Do not use on weighted silk.

Cream of tartar. Boil the stained article in a liquid made up of 4 teaspoons of cream of tartar to 1 pint of water. Rinse thoroughly.

Hydrosulfite. Hydrosulfites available at drug stores as color removers or dye-stripping agents also will remove rust stains. Follow directions given on the package. Do not use on weighted silks.

Lipstick and rouge. For the removal of stains made by lipstick and rouge, these methods are suggested.

Vaseline and carbon tetrachloride. If water spots the cloth, work vaseline or lard into the stain. Then either sponge with carbon tetrachloride or dip the stained part in a bowl of the solvent. If a trace of color remains sponge with denatured alcohol. On acetate rayon and colored materials, dilute the alcohol—1 cup denatured alcohol to 2 cups water.

Glycerine, soap, and water. If the material is washable, first loosen the stain as above with glycerine or vaseline. Then launder as usual. If soap or other alkalis are applied before the stain is loosened, they are apt to set it.

Hydrogen peroxide and sodium perborate. Sponge with sodium perborate-hydrogen peroxide mixture (1 teaspoon sodium perborate to 1 pint peroxide. Rinse thoroughly. If the stain persists,

sprinkle powdered sodium perborate on the dampened area and let stand for half an hour. Finally rinse well. Be sure to test the cloth for colorfastness before using these bleaches.

Meat juice or gravy. Sponge meat-juice or gravy stains with cold or lukewarm water. Never use hot water; it sets the stain. If a grease spot remains, launder washable materials in warm soapy water. If the cloth is not washable, use an absorbent powder or a grease solvent.

Absorbents. Dust the powder over the stain, let it stand until it absorbs the grease, then brush off.

Solvents. Sponge with carbon tetrachloride, gasoline, or benzene.

Medicines. Because of the great number and variety of substances used in medicines, it is not possible to give methods for removing all such stains. If you know what the medicine is made of, it will aid in choosing the remover. For instance, a tarry or gummy medicine can be treated in the same way as a tar spot (see p. 556); a medicine containing much iron can be removed in the same way as iron rust (see p. 552). Medicines in a sugar sirup usually can be washed out with water; those dissolved in alcohol sometimes can be removed by sponging the stain with alcohol. Many of the medicines used in swabbing sore throats contain silver nitrate and should be sponged with a solution of sodium thiosulfate ("hypo")—1 teaspoon of the crystals in 1 cup of water.

If you cannot find out what kind of medicine caused the stain, you may have to try several methods to find one that will do the job. Each of the following methods will remove certain medicine stains.

Boiling water. For washable materials, pour boiling water on the stain from a height of 3 or 4 feet, as for fruit stains, or launder in warm soapy water.

Denatured alcohol or carbon tetrachloride. Some color stains can be sponged or soaked out with alcohol. Sponge greasy stains with carbon tetrachloride. A dry-cleaning soap helps to loosen them. Finally sponge with fresh carbon tetrachloride.

Bleaches. Use bleaches only on white materials. Try one of the following:

Hydrosulfite. Use one of the hydrosulfite dye-stripping agents available at drug stores. Follow instructions on the package.

Javelle water. For stains on linen, cotton, or rayon, dip in Javelle water for 1 minute (no longer), remove the chlorine from

the cloth with a sodium thiosulfate solution, rinse well in water. (See p. 544 for more detailed instructions.) Do not use Javelle water on silk or wool.

Metallic stains. The tarnish of copper, brass, tin, and other metals often stains textiles. To remove, apply vinegar, lemon juice, or a 10 per cent solution of acetic acid. Rinse well as soon as the stain has dissolved. Do not use chlorine bleaches or sodium perborate to remove these stains.

Mercury or quicksilver removes lead or solder stains from rugs or clothing. First scrape off as much of the lead as possible with a dull knife. Then pour mercury on the stain and work with a stick until the mercury absorbs the stains.

Mildew. Mildew spots must be treated when fresh, before the mold growth has a chance to weaken the cloth.

Soap and water. On washable material, soap and water will remove very fresh stains. Drying on the grass in the sun helps to bleach the spots.

Bleaches. Try a bleaching agent if soap and water do not remove the stain. Be sure to test for colorfastness on a hidden part of the garment.

Lemon juice. Moisten the stain with lemon juice and salt and place in the sun. This often removes slight stains.

Javelle water. Old stains on cotton, linen, or rayon may be bleached out with Javelle water. Dip the stain in the Javelle water for 1 minute (no longer), remove the chlorine from the cloth with a sodium thiosulfate solution, rinse well in water. (See p. 544 for more detailed instructions.) Do not use Javelle water on silk or wool.

Sodium perborate. Soak the stain in a sodium perborate solution (4 tablespoons perborate to 1 pint lukewarm water). Or dampen the stain with water and sprinkle the perborate powder directly on the stain. Rinse after either treatment.

Mud. Let the mud stain dry, then brush well. Sponge with clear water, or use soap and water if it will not harm the cloth. Sponging with alcohol will help to remove the last traces of the stain. On colored materials and acetate rayon dilute the alcohol—1 cup denatured alcohol to 2 cups water.

Pencil marks. The methods for removing indelible and lead pencil marks are listed as follows.

Indelible pencil. Do not use water on indelible pencil marks as this spreads the dye and makes the stain harder to remove. Use one of the following:

Denatured alcohol. Soak the stain in alcohol. If carbon marks remain, sponge with soap and water. Do not use alcohol on acetate rayon. Test all dyed cloth for colorfastness.

Bleaches. Remove the dye with a bleaching agent.

Javelle water. For stains on uncolored cotton, linen, or rayon, dip in Javelle water for 1 minute (no longer), remove the chlorine from the cloth with a sodium thiosulfate solution, rinse well in water. (See p. 544 for more detailed instructions.) Do not use Javelle water on silk or wool.

Hydrogen peroxide and sodium perborate. For other materials sponge with a mixture of 1 teaspoon sodium perborate to 1 pint peroxide. Rinse well.

Lead pencil. A soft eraser sometimes will remove the marks, especially on stiff or starched materials. If the material is washable, rub soapsuds into the stain and launder as usual. Sponge woolen materials with clear water or with a solution of equal parts alcohol and water.

Perspiration stains. Perspiration of the body is usually acid, so you can sometimes restore colors changed by a perspiration stain by treating with an alkali. Dampen the stain with water and hold it over the fumes from an open ammonia water bottle. (See Acids, p. 543.) Old stains may be alkaline; then try vinegar. However, colors changed by perspiration cannot always be restored, particularly if the stain is an old one.

To remove perspiration odors, sponge the stained part with warm water to which a few drops of vinegar have been added, sprinkle powdered pepsin over the stain, work it well into the cloth, and let stand 1 to 2 hours, keeping the spot moist. Then brush off the powder and rinse well.

Yellowish perspiration stains on white material can be removed by:

Soap and water. If the material is washable, bleach in the sun after washing in soap and water.

Bleaches. For a stubborn stain, try a bleach.

Hydrogen peroxide. Sponge with hydrogen peroxide or a mixture of 1 teaspoon sodium perborate to 1 pint peroxide. Rinse with water.

Sodium hydrosulfite. Quickly dip the stain into a sodium hydrosulfite solution (2 teaspoons sodium hydrosulfite to 1 pint water). Rinse immediately. First test the colorfastness of the cloth to this bleach.

Scorch. You can usually remove light scorch stains from cotton

and linen materials, but wool and silk can seldom be restored to their original condition. Brushing with emery paper may improve wool, however. Try the following:

Soap and water. If the cloth is washable, soap and water will remove very slight stains. After washing, place the article in the sun for a day or two; it may bleach out any remaining traces of the stain.

Hydrogen peroxide. If the stained material is white, use hydrogen peroxide. Dampen a white cotton cloth with the peroxide and lay it on the stain. Cover with a clean dry cloth; then press with a medium warm iron. If the hydrogen peroxide soaks through the top cloth, replace with a dry one. Ironing directly on the cloth moistened with peroxide or on the dampened stain itself, after the cloth has been removed, will cause rust stains on the garment. Repeat the treatment, until the stain is completely removed. Rinse well.

Light scorch stains may be removed also by sponging with hydrogen peroxide to which sodium perborate has been added (1 teaspoon sodium perborate to 1 pint peroxide). Rinse well with water.

Shoe dressings. For the removal of stains made by shoe dressings, the following methods are suggested.

Soap and water. If the material is washable, remove fresh stains from one of the paste dressings by sponging or washing thoroughly with plenty of soap. For spots caused by white dressings, sponge first with water, then with soap and water.

Solvents. Sponge well with carbon tetrachloride or turpentine. Glycerine, lard, or vaseline worked into the stain first helps to loosen it. For liquid dressings and for stains on wool, sponge with denatured alcohol. Do not use alcohol on acetate rayon or colored cloth.

Bleaches. If a dye stain remains, remove with a bleaching agent.

Hydrosulfite. Apply one of the hydrosulfites available at drug stores as a color remover. Follow directions on the package.

Hydrogen peroxide or sodium perborate. Sponge the stain with hydrogen peroxide or with a sodium perborate solution (p. 546) or sprinkle sodium perborate powder on the moistened stain directly. Rinse well.

Tar, road oil, asphalt, axle grease, pitch. Stains made by tar-like substances are hard to remove, especially from cotton mate-

rial. First rub in vaseline or lard to soften the stain, then sponge with one of the grease solvents—carbon tetrachloride, Stoddard solvent, gasoline, benzene—or dip the article in the liquid and rub lightly between the hands. Repeat the treatment until the stain is removed. If the material is washable, use warm soapy water after rubbing in the vaseline or lard.

For stains on carpets or rugs, scrape off as much as possible with a dull knife. Then sponge with the grease solvent, using a brushing motion so that you do not rub the stain into the carpet.

Tobacco. Treat stains from the tarry substances in the stem of a pipe in the same way as tar. Use one of the following methods to remove tobacco juice stains:

Cold water and glycerine. Sponge with cold water; then work warm glycerine into the stain. Let stand for half an hour, and wash with soap and water. If the stain cannot be completely removed by washing, bleach it in the sun. Moistening it with lemon juice makes it disappear more quickly.

Wood or denatured alcohol. To remove traces of color remaining on wool materials after the above treatment, sponge with alcohol.

Bleaches. Try one of the following to remove remaining tobacco stains:

Hydrogen peroxide or sodium perborate. Sponge with hydrogen peroxide or with sodium perborate solution (4 tablespoons to a pint of water). Or sprinkle powdered sodium perborate on the moistened stain. Rinse thoroughly.

Javelle water. For stains on cotton or linen, dip the stain in Javelle water for 1 minute (no longer), remove the chlorine from the cloth with a sodium thiosulfate solution, rinse well in water. (See p. 544 for more detailed instructions.) Do not use Javelle water on silk or wool materials. Be sure to test the cloth for colorfastness before applying this bleach.

Tomato juice and catsup. For the removal of stains caused by tomato juice and catsup, the following methods are suggested.

Cold water and glycerine. Sponge the stain thoroughly with cold water to remove all the loose foodstuff. Next work glycerine into the stain, and let stand for half an hour. Then wash with soap and water.

Hydrogen peroxide or sodium perborate. Remove any remaining stain by sponging with hydrogen peroxide or with sodium

perborate solution (4 tablespoons to 1 pint of water). Sponge or rinse with cold water.

Urine. These stains differ so in composition that it is impossible to give methods which will be successful in all cases. If the color of the cloth is not destroyed but only changed, it may be restored. Normal human urine is usually acid, as is also that of all meat-eating animals. Therefore sponge such stains with a weak ammonia or soda solution. (See Acids, p. 543.) If the stain is alkaline, sponge with lemon juice or vinegar. (See p. 544 for more detailed instructions.)

Warm water followed by salt and water. Sponge with warm water. Warm salt water may be used (about $\frac{1}{2}$ cup salt to 1 quart water). Apply and let stand 15 minutes; then sponge with clear water.

Hydrogen peroxide or sodium perborate. Apply a few drops of hydrogen peroxide or sponge with a mixture of 1 level teaspoon sodium perborate to 1 pint peroxide. Powdered sodium perborate may be sprinkled on the dampened stain. Rinse thoroughly in water.

Suggestions for the Laboratory

Determine the comparative hardness of water by titrating, using methyl orange as an indicator.

Determine the comparative hardness of water by adding soap solution until a permanent suds is formed.

Use four types of commercial softeners in the proportions indicated on the package to soften water. Determine the comparative hardness of the water so treated.

Determine the comparative alkalinity of various commercial soaps by testing an alcoholic solution with phenolphthalein.

Test the shrinkage and color changes which result from laundering. A, lukewarm and hot solution of neutral soap; B, lukewarm and hot solution of alkali soap.

PROBLEM 2. HOW CAN DRY CLEANING BE USED IN THE CARE OF FABRICS?

When the nature of the fabric is such that cleansing by laundering as already described cannot be used, dry cleaning is an accepted method of removing soil. At present, dry clean-

ing is a flourishing industry in the textile field and the development has occurred largely within the last twenty-five years. The use of the services of the dry cleaning plant in the care of fabrics is more common than is the case with laundries. Perhaps a ready explanation for this is found in the inflammable nature of the solvents commonly used, and in the need for skill and special equipment to secure satisfactory results. Whether it is possible to do dry cleaning at home or not—a procedure often questioned because of the danger involved—it is desirable to understand the processes involved and the possible effects.

The rapid development of new fibers and new finishes presents many complex problems to dry cleaners. Aralac, which is commonly blended with rayon, wool, or cotton, can be handled satisfactorily in dry cleaning. Vinyon, as described earlier, cannot be cleaned with ordinary methods as it melts below the standard ironing temperatures. Glass fabrics cannot be cleaned satisfactorily because there is considerable slippage of yarns, fraying of seams, and the fabric becomes lustrous. In many instances printed designs are not fast to cleaning because the adhesive used in applying the pigment to the glass fabric is removed by the spotting agent used. It is expected that improvement in the fabric or in dry-cleaning methods will be made in the near future so that glass fabrics can be cleaned successfully.

Plastic-coated fabrics and fabrics made from plastic-coated yarns require special care in dry cleaning as each type of material possesses different properties. It will be necessary, therefore, to recognize these materials in order to handle them successfully.

The finishes that make a fabric crush-resistant and water-repellent, and give it a permanent body, may be an aid or a hindrance to the dry cleaner and laundry operator. The many mixtures of fibers and combinations of weaves used in fabrics make it more difficult for the operators to determine the kind of fiber or fibers they are handling.

Dry-cleaning agents. Stoddard solvent, the first solvent used in this country, is used in most cleaning plants today. It is a

high-boiling petroleum product. Synthetic noninflammable solvents are also in common use. Carbon tetrachloride was the first synthetic solvent to be produced. As the result of further research, trichlorethylene was developed. It is less volatile than carbon tetrachloride, so offers less of a health hazard, and there is less loss due to evaporation. In 1934 perchlorethylene, a third synthetic solvent, was introduced by E. I. du Pont de Nemours and Company. The appearance of this new solvent has had the following result:

All new washer dryer recovery types of machines which have come in the market have been designed to handle perchlorethylene, and many of the older machines have been converted to use this fluid.

The advantages of chlorinated hydrocarbon cleaning systems as compared with the older naphtha systems are:

1. Noninflammability of the fluid, which permits the installation of machines in places where fire regulations would not permit unit using an inflammable fluid.
2. Compact machines using small floor space per unit of production and requiring little high-priced labor.
3. Rapid and odorless cleaning geared to meet the demands of present-day customers.
4. Cleaning costs as low as plants using a petroleum distillate.
5. Reduced finishing cost due to ease of spotting and finishing after cleaning.

All these advantages were not evident in the early synthetic fluid systems, but as developments occurred additional features were noted. Different systems and fluids had these advantages in varying degrees.¹

Chloroform, ether, and carbon bisulfide, along with a number of other substances, are used as special stain removers. These solvents, in the concentration in which used, do not affect the natural fibers in any way. Shaping, pleating, and the like are not altered by their use, so that costumes and articles cleaned by them retain their shape. Soap, prepared to be used with these solvents and soluble in them, is important in

¹ N. C. Cooper, "Recent Developments in Textile Cleaning and Finishing," *Textile Colorist*, Vol. 61 (1939), p. 811.

dry cleaning. This soap acts as a vehicle and a detergent in the removal of soils and stains.

A procedure approved by the majority of dyers and dry cleaners is as follows:

1. *Marking in.* Each garment of every package is tagged alike with the customer's number and the number of pieces, being examined at this time for rips, missing buttons, possible damaged portions, and the general condition of the garment. Badly damaged articles are received and cleaned only at the owner's risk. Buckles and ornaments that might be injured by the solvent are removed. If the garment is likely to shrink, it is measured.

2. *Sorting.* Ladies' coats are handled as a separate class. Silks and wools are also separated, and the groups further divided into lights, mediums, and darks, each subdivision being handled separately.

3. *Cleaning.* With the exception of silk-lined coats, all silks and wools are first run in a ten-minute "break" of clear solvent to remove loosely bound dirt. A machine, similar to the wash wheel in the laundry, is used. It consists of a rotating perforated wheel in a steel shell which revolves a definite number of times in one direction and then reverses its action to prevent the "balling" of the material. The lifting and dropping of the garments by this action affords the agitation necessary to free the fabric from the loose soil.

On the completion of this treatment, the articles are transferred to clean solvent again. The garments are run in a continuous flow of fresh solvent, the process being continued until the solvent flows clear.

The next step is the removal of all traces of the solvent. With silk this is accomplished by first extracting the solvent as water might be extracted from a garment, and then hanging the garments to dry in a deodorizing cabinet, which has a current of warm air forced through it to accelerate deodorizing.

After woolens have been extracted, they are then placed in a tumbler for deodorization. They are first treated with hot air and steam, and then with hot air alone. Machines used

through the cleaning process are grounded to prevent possible electric discharge which might ignite the highly explosive solvent. Other special precautions are generally adopted by the trade to lessen the danger of dry cleaning.

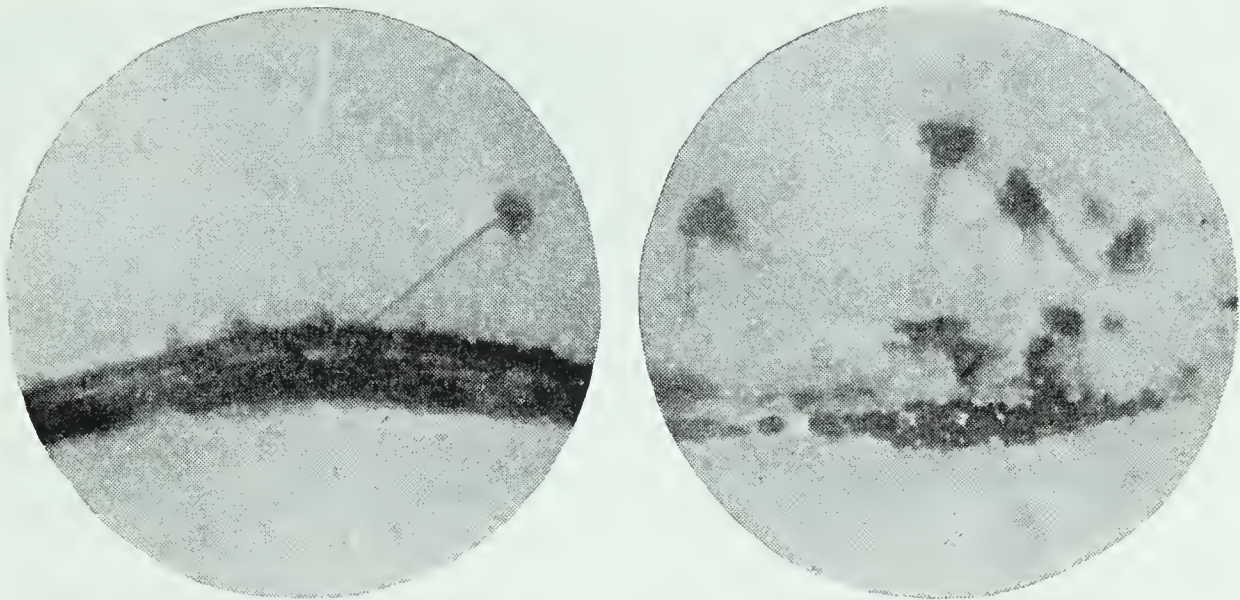
If garments are badly spotted it is necessary for them to be wet cleaned at this point. If measurements were not taken when the goods were received they are secured now. The articles are treated with soap and water and then stretched back to size and shape in finishing. The number of articles needing to be wet cleaned varies from 2 to 3 per cent in a reliable plant to as high as 50 per cent in a low-grade plant.

Garments that do not receive wet cleaning are sent to the spotting department where they are examined for stains not removed in the cleaning. These stains are generally water rings, grease spots, blood, and water-soluble foods which may be removed by special reagents.

4. *Finishing.* In the finishing department they are pressed either by hand or by machine, and buttons, buckles and ornaments are sewed on. A final inspection is given each piece before it is ready for delivery.

Cleaning in the home. If the cleaning of fabrics can be done by the use of these solvents without deterioration, what place may dry cleaning come to have in our routine care of household fabrics? What limitations are there to its practice in the home?

If the trend of the future is to be predicted from that of the past, there will be increasing use of dry cleaning as a measure of freeing household and personal fabrics from soil. It seems probable, however, that dry cleaning will remain largely a trade activity. What reasons can you give for this? First, the danger involved in handling the inflammable solvents makes their home use questionable and, under some city fire rules, impossible. Second, the fact that the solvent should be used in about the same quantities that water should be used in laundering makes home dry cleaning of a piece or two expensive. Third, the use and manipulation of special solvents for spots requires information and technique that is largely in the possession of the trade only. The need for space for



Photomicrograph by Schwarz

Left, mold on silk, showing mycelium, spore head, and spores. Right, mold on rayon (viscose).

airing and conditions desired for deodorizing as well as the difficulty of deodorizing at home are further reasons for the limitation of dry cleaning as a home treatment of textiles.

PROBLEM 3. HOW MAY THE LOSS FROM MILDEW, MOTH, AND BEETLES BE PREVENTED?

Mildew and mold. Mildew and mold are common causes of loss to manufacturer and consumer because of their destruction of textile fabrics, especially cotton materials. Although dating from the beginning of the industry, the problem of preventing mildew yet remains unsolved.

Mildew is caused by the growth of microscopic living organisms usually classed as part of the plant kingdom and referred to as molds. (See the illustration above.) These molds resemble closely the microscopic organisms which cause rust, smuts, blights, and scabs on vegetables and grains. These organisms, known as fungi, require dead vegetable matter for at least part of their food.

The fact that there are many species of molds capable of growing on textiles makes the problem difficult to handle. These microorganisms are found in the air and in the soil.

Some types require a large percentage of moisture for their growth but can thrive at low temperatures; other types can grow where little moisture is present, but require high temperatures.

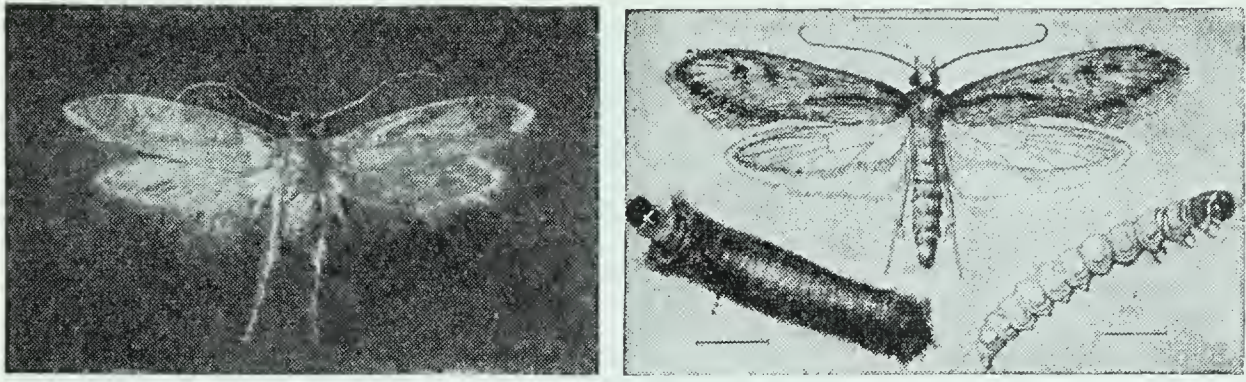
These microscopic organisms develop by means of a fine network of filaments that penetrate the fabric to extract and convey food. These bodies, known as mycelium, are colorless, and their presence in a cloth cannot be detected until the colored spores or seeds have developed which give to mildew its characteristic color and appearance. Many spores in the form of spore heads are barely visible to the naked eye. The individual spores are found everywhere and under favorable conditions will develop into their specific type of mold.

Raw cotton furnishes ample food for many types of mold and the infection is not dependent upon the presence of starch or other sizing. Antiseptics that prevent the growth of some types of mold prepare the best conditions for the growth of certain other types. An increase of moisture content and temperature invariably increases the development of common types of mildew. The best-known prevention of mildew at present is to keep fabrics as dry and cool as possible.

The clothes moth. The clothes moth causes as great a loss to wool material as does mildew to cotton. The life cycle of the clothes moth is strikingly similar to that of the silkworm, consisting of the four stages, egg, larva, chrysalis, and moth. (See page 565.)

There are two distinct types of these moths that live on animal fibers and cause the annual loss of some \$100,000,000 to consumers alone.

They differ mostly in the type of cocoon in which they pass their dormant stage, and have been named accordingly as webbing and case-making moths. (See page 565.) The first forms a silken web around its body; the latter produces a hard case or shell in which to pass its pupal stage. Like the silkworm moth, the female clothes moth seldom flies, but spends her life of a few days laying eggs. These eggs she places as near as possible to large sources of the best food, which is the finest type of wool or other animal fibers available. The tiny eggs are there-



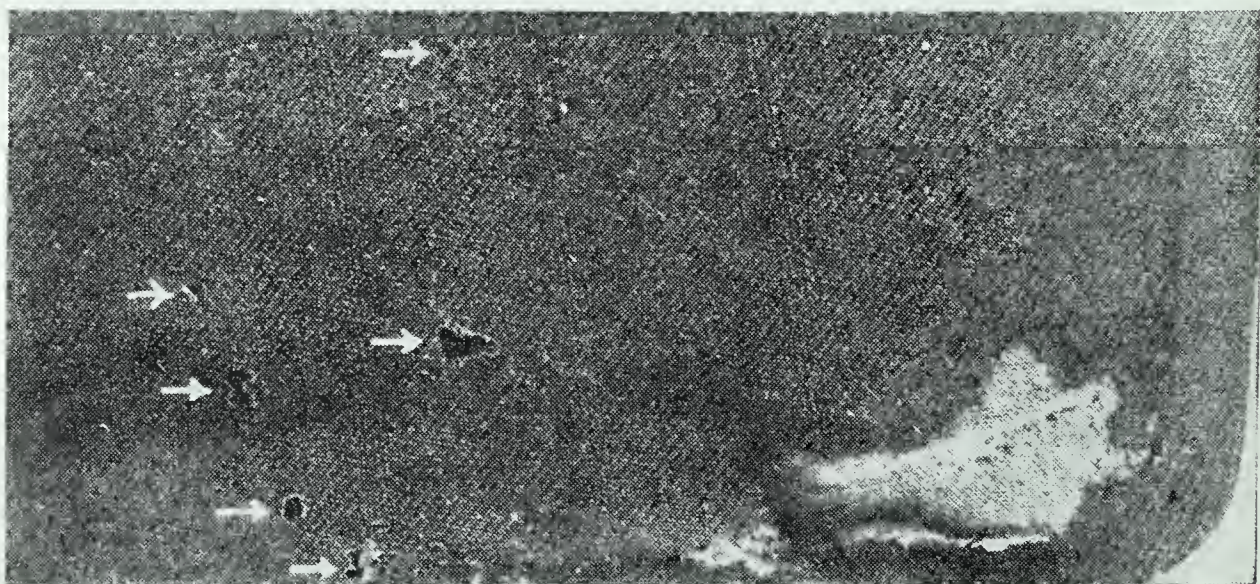
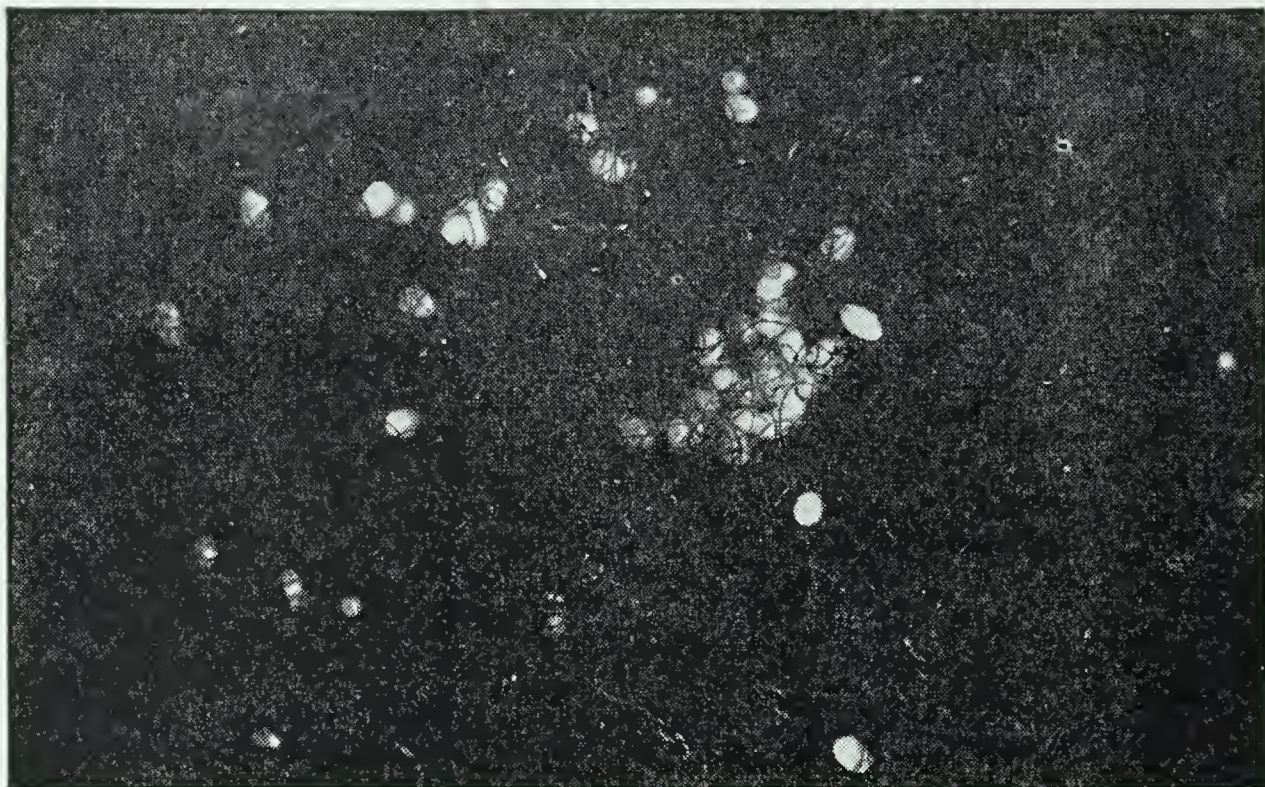
Courtesy Bureau of Entomology and Plant Quarantine, U. S. D. A.

Clothes moths. Left, webbing moth. Right, case-making moth: adult, larva, and larva in case.

fore embedded deep in the pile of some kind of wool cloth, and held closely because of their sticky or gluey nature. Though easily broken, they cannot be removed by brushing or vacuum cleaning. Heat is necessary to hatch the worm, or larvae, which is white in color and about .05 of an inch in length. During the larval period, which is the only destructive period of their life, these worms eat many times their own weight of animal fibers. In due time they form their cocoon, lie dormant for a few weeks, emerge as millers or moths, and so begin another cycle which is unending in its repetition and destruction. Although animal fibers are the only fibers that serve as food for these moths, the case-making type will use any type of fiber for case making. The tobacco or carpet beetle is another insect pest causing great damage to heavy fabrics. It is perhaps less frequently recognized than the clothes moth.

Carpet beetles. Carpet beetles of various types cause great loss to all kinds of fabrics. According to E. A. Back,¹ U. S. Department of Agriculture, there are four types of these beetles commonly found, namely, the common carpet beetle, the furniture carpet beetle, the black carpet beetle, and the varied carpet beetle. The fact that none of these beetles in any stage of their growth is more than three-sixteenths to one-fourth of an inch in length makes their detection difficult. The adult is a hard-shelled beetle broadly or elongate oval. It is the larvae of the carpet beetles that feed on fabrics of all types. The larvae or grubs of all carpet beetles, except the black, are more

¹ E. A. Back. "Carpet Beetles." Leaflet No. 150. U. S. Dept. of Agriculture.

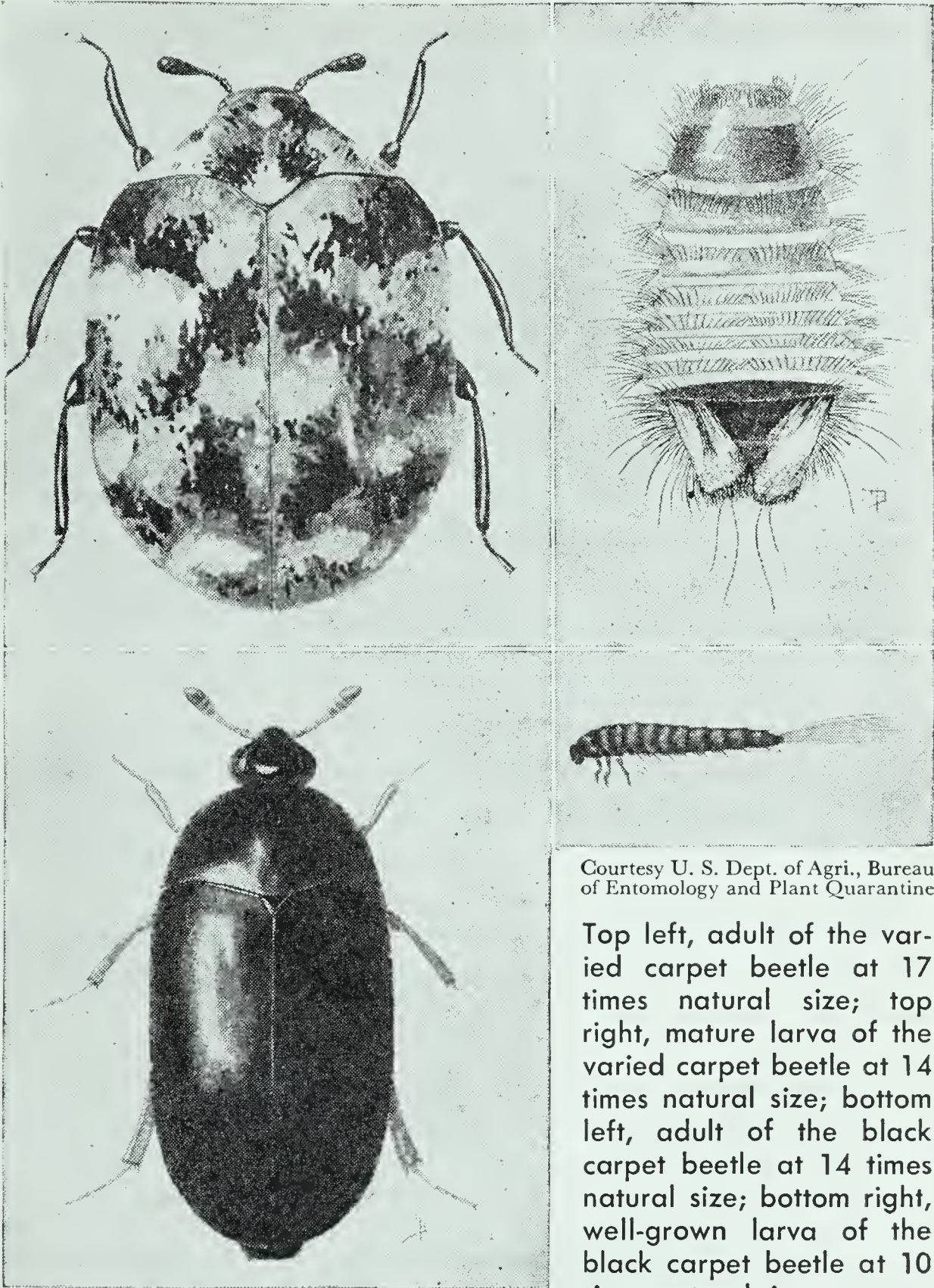


Courtesy Bureau of Entomology and Plant Quarantine, U. S. D. A.

Top, the webbing clothes moth eggs, laid in nap of cloth. Bottom, section of man's coat damaged by case-making clothes moth.

or less oval in shape and have a blackish or brownish appearance. The larva of the black carpet beetle is easily distinguished from the others by its golden, yellowish or chocolate color. (See page 567.)

Carpet beetles pass through the four stages common to most insects: that of egg, larva, pupa, and adult. The tiny adult beetles are often found crawling on the window sills or



Courtesy U. S. Dept. of Agri., Bureau of Entomology and Plant Quarantine

Top left, adult of the varied carpet beetle at 17 times natural size; top right, mature larva of the varied carpet beetle at 14 times natural size; bottom left, adult of the black carpet beetle at 14 times natural size; bottom right, well-grown larva of the black carpet beetle at 10 times natural size.

out of doors in the sunlight. They fly readily and may fly from house to house. The female deposits her eggs in cracks in the floor or behind baseboards as well as in clothing and upholstered furniture. If conditions are favorable the eggs

hatch in a few days but about one year is required to complete the life cycle. The larvae shed their skins from six to eight times during growth. They eat ravenously except just before shedding their skins or shells. For this molting period they crawl behind mantels or baseboards or in cracks, sometimes far from any source of food. This habit makes control difficult as sprays or fumigants do not readily reach them in their hiding places.

Some studies have tended to prove that the varied carpet beetles prefer nylon to wool and when their favorite food is not available will feed on rayon and even cotton. Sprays that prove to be insecticides to most clothing pests are only repellents to the varied carpet beetle. Fabrics sprayed with most of the common moth-proofing compounds do not prevent the clothes moth and most dermestides from eating them but result in death after feeding. Varied carpet beetles placed on these same treated fabrics refuse to feed and if possible will attack other types of cloth.

Experience has taught us that clean clothes are in less danger of being infested by moths and other pests than are soiled clothes; that air and sunshine tend to destroy the moth; and that dry cleaning or laundering destroys all stages of these pests.

Methods of control. The following methods of control are given by the United States Department of Agriculture: ¹

CONTROL

Clothes moth control is sometimes complicated because many different things have to be considered. Judgment must be used in selecting the method of control suited to special needs. When moths are all over a house, drastic measures such as fumigation or extensive spraying may be required. More often, local treatments will be enough. Most of the practices used against clothes moths will also be helpful in preventing damage by carpet beetles and some other household pests.

Fumigation of the entire house. Most materials commonly used as house fumigants, such as hydrocyanic acid, chloropicrin, and

¹ U. S. Department of Agriculture, Clothes Moths Leaflet No. 145, Revised 1947.

methyl bromide, are poison gases dangerous to human life. Fumigation should not be attempted by individuals who are not thoroughly familiar with handling these dangerous materials. It should be done by licensed pest-control operators, who will assume all the responsibility and work under local health-department regulations. Fumigation is out of the question in some congested areas and in apartment houses.

Printed directions on fumigation are available on request from the United States Department of Agriculture. No fumigation with a dangerous gas should be permitted in any part of a dwelling while other portions are occupied.

Contact Sprays. Sprays available at stores under trade names usually consist largely of a highly refined, odorless and stainless kerosene oil plus toxic ingredients. Some of these sprays may contain DDT in qualities ranging from 0.5 to 3 per cent. These sprays are intended primarily as contact sprays—that is, for destroying the insects actually hit. However, those of the higher DDT content, if applied to surfaces in considerable amounts, may kill some of the insects that subsequently crawl over the residue.

Contact sprays are used to destroy moths on clothing and furniture, in floor cracks, about baseboards, and elsewhere. They can be applied with hand sprayers, but are best applied with power sprayers. Many insect exterminators or pest-control operators have excellent power-spraying equipment for treating cracks that are inaccessible with the ordinary hand sprayer. Vaporizing machines, which merely fill the room with a fine mist, are of little practical value in moth control.

Do not spray an insecticide containing inflammable solvents where there are open flames or fire of any kind.

Aerosol Bombs. The insecticides in the present aerosol bombs are usually pyrethrum extract and DDT. The fog produced by these bombs remains floating in the air for several minutes to more than an hour, and in rather heavy doses will kill exposed clothes moths and carpet beetles. However, it may not penetrate infested garments or cracks, and hence is not a practical method of controlling these pests, although repeated applications may have some beneficial effect.

Mothproofing solutions. There are on the market today a number of solutions which, when applied to clothing, rugs, drapes, furniture covers, etc., are said to make them immune to moth attack. No solution will absolutely and permanently mothproof

fabrics, although certain ones, when applied in the hot dye bath during the manufacturing process, more nearly achieve this desired result. It appears, however, that the better solutions now available, when applied so that the fabric becomes thoroughly wet, impart a resistance to moths that is of practical value. Dry cleaning, washing, and exposure to light usually lessen in some degree, depending on the nature of the mothproofing solution used, the moth-resistant quality imparted by the original treatment. Most commercial mothproofing solutions contain fluorine compounds, usually fluosilicates, as the active ingredient. Such solutions are readily removed by thorough washing in water, while solutions with a naphthalike base are equally well removed by dry-cleaning processes. The United States Department of Agriculture does not recommend mothproofing solutions that depend for their effectiveness upon arsenic in any form or amount.

Use of DDT. There are indications that DDT may be used for controlling clothes moths, but further investigations are necessary to obtain the information required to make definite recommendations. At present we suggest that a 5-per cent solution of DDT in deodorized kerosene may be used to spray on closet walls, around baseboards, on floors, on carpets, or on other surfaces where the insects are developing or where they will come in contact with the DDT deposit that is left after the liquid has evaporated. Apply just enough spray to moisten the surface being treated. As the DDT residue will be effective for several weeks to several months, frequent treatments are not necessary.

When closet walls have been sprayed, moth adults crawling over them will be killed, but larvae in untreated clothing will not be affected, because DDT has no fumigating effect. We do not yet know the best way to use DDT as a mothproofing treatment, but the 5-per cent solution may be used for spraying on clothing or other fabrics to control larvae and help prevent feeding damage. Spray lightly all over the fabric on both sides.

Do not use this spray near a fire. Wash your hands when you are through spraying. After the oil has dried, the DDT deposit is not harmful.

Dry cleaning. Dry cleaning kills all forms of moths present at the time of treatment, but does not impart moth resistance.

Washing. Washing in a strong solution of neutral soap kills all moths but does not protect against reinfestation.

Wrapping in paper bundles. Clothing just dry-cleaned or

washed, if wrapped in paper with its edges well folded back or sealed carefully, will remain free from moths indefinitely if the paper is not broken. Sealing in unbroken hat boxes or other cardboard boxes will accomplish the same result. The addition of some flake naphthalene is advised, to destroy any moths which may have gained access to the clothing before it was wrapped.

Cold storage. Cold storage is excellent for the protection of furs, garments, rugs, or anything else from moth injury.

Fumigable storage. Fumigable commercial storage is excellent for the protection of furs, clothing, furniture, and other articles from moth injury.

Cold weather. Clothes moth larvae are incapable of causing harm at 50° F. or below. They are killed within 1 to 2 days by zero temperatures, and articles such as clothing, rugs, and furniture exposed to zero weather will be freed of moth life. Moth larvae have lived 67 days at 20° to 25° F., and 283 days at 30° to 35° F. In most parts of the country cold weather has little effect upon moths in buildings.

Heat. All forms of moths are killed upon exposure for a short time to temperatures of 125° to 130° F. Newly hatched larvae die at 100° F. Where heat penetration is required, as in upholstered furniture, the interior itself, not the air about it, must be raised to 125° to 130° F. Where heating facilities are available, entire houses can be superheated during hot summer weather, and this can be effective in destroying not only clothes moths but other common house pests such as carpet beetles and bedbugs. About 12 hours are required to get the desired temperature everywhere in the house.

Sunning and brushing. The soft eggs are easily crushed or dislodged by thorough brushing. Pay particular attention to all seams, pockets, etc. Moths cannot stand bright sun. Larvae drop to the ground from clothing left hanging in the sun on the line, especially if no folds are present in which they can find protection from the light rays.

Good housekeeping. In combating clothes moths it is important to keep floors and rugs well vacuum-cleaned or swept. Woolen garments kept in closets and not packed away for the summer should be frequently sunned and brushed, and care should be taken to keep all woolen materials off the floor. Woolen rags or discarded woolen clothes left carelessly about the house are often a source of serious moth infestations.

Treatment of articles in trunks and chests. Articles in a trunk, chest, or wooden box, reasonably tight, can be protected perfectly during the summer by scattering between the folds of the clothing, preferably between sheets of thin clean paper, 1 pound of either flake naphthalene or paradichlorobenzene. Keep all covers tightly closed. Four ounces will give protection under ideal conditions. These chemicals are cheap; it pays to overdose and be safe.

Treatment of closet contents. To control moths in a closet, brush thoroughly all clothing, clean the closet thoroughly, and seal all cracks in the plaster and about baseboards with crack fillers. Equip doorframes with rubber or felt gaskets against which the door can be shut tight at all points. Place on the top shelf, or hang in muslin bags from hooks, 1 pound of either flake naphthalene or paradichlorobenzene to each 100 cubic feet of closet space. The fumes given off by the slow evaporation of the crystals quickly stop moth larvae from feeding and ultimately kill them if the fumes are retained long enough in proper concentration. It is therefore important that the concentration of the fumes be maintained by making sure that the closet is perfectly tight and has a tight-fitting door that is kept closed except for brief periods when clothing is being put in or taken out. Set aside a closet to be used only for storage or, better yet, build a closet in the attic large enough to hold anything, including superfluous upholstered furniture, and keep it well stocked with flake naphthalene.

Paper bags. Garment bags are of no value in themselves for killing moths, but if clothing free from moths is put into an unbroken garment bag that is tightly closed and sealed, the paper will keep moths out indefinitely. Once the moths get into the bags, either with the clothing or through breaks in the paper or at the fastenings, damage will result. The smell of cedar or pine oil in the bag will not prevent this. Printer's ink on newspaper has no protective value.

Cardboard closets. Cardboard closets are of very doubtful value. Many are worthless. If very tight, they protect after the fashion of paper garment bags. The cedar or pine oil in these cardboard closets or boxes is of no practical use.

Cedar-lined closets. Cedar-lined closets as ordinarily installed in the average home cannot be depended upon to protect clothing from moths.

Cedar chests. Chests of red cedar (*Juniperus virginiana*) made of $\frac{3}{4}$ -inch heartwood to the extent of 70 per cent of the chest

proper are dependable protectors of clothing from moth attack *provided they are tight and in good condition and the clothing is freed from the larger moth larvae before it is placed in them.* Chests of neutral woods lined with a thin cedar veneer are not dependable. Cedar chests may be veneered on the outside with hardwoods, such as walnut or mahogany, without affecting their value as moth protectors.

Piano felts. Hang 4 ounces of paradichlorobenzene in a muslin bag inside the piano case, and close all openings in the case and keep them closed as much as possible during the warm weather. Do not apply spray to the piano felts unless the maker of the spray guarantees to make good any injury to wires or other parts.

Rugs and carpeting. Clean rugs carefully on both sides, preferably with a vacuum cleaner. Scatter over the upper surface enough flake naphthalene to make the rug appear white. Roll it tightly on a pole and wrap the roll securely in unbroken paper, making sure that the paper extends well beyond the ends of the roll and is carefully folded back several times upon itself and tied so that no moths can enter from the ends. Make a wooden box, tin-lined, with tight cover, and large enough to hold rugs not needed during the summer, to keep in the attic. Rugs sent to be cleaned and stored in well-equipped storehouses are perfectly protected. When carpeting is fastened to the floor, as in churches, auditoriums, theaters, hotel rooms, etc., supplement vacuum treatment with spraying or treatment with mothproofing solutions, or both. If the floor covering extends only to within 6 inches of the edge of the room, it can be cleaned more effectively. Moths make no headway in a properly cleaned floor cover. They thrive best in carpeting beneath heavy pieces of furniture that are not moved often, and close to a wall where the larvae can grow unmolested by house cleaning.

Furniture. Upholstered furniture with covers containing animal fibers has in the past been very seriously damaged by moths feeding not only between the rows of pile on the surface but also on the threads where they pass beneath the warp. Many covers containing wool and mohair are today factory-treated to render them moth resistant, and these should have preference over untreated covers. Covers of cotton, linen, and rayon are not injured by moths. Moths in furniture can be killed best by having the infested pieces fumigated by furniture-storage warehouses or other concerns offering a fumigation service, or they can be treated with

a contact spray by means of a power sprayer. Susceptible covers should be kept brushed carefully and frequently, and where slip covers are used they should be removed at frequent intervals so that the furniture can be brushed or vacuum-cleaned. Where fumigation or spray services are not available, furniture can be placed on open porches in summer and saturated with a good grade of clear gasoline, care being taken to keep fire away in all forms. In some sections, furniture can be exposed to zero temperatures for 2 days and be rid of living moths.

Fabrics moths do not eat. Moths do not eat cotton, linen, rayon, or other fabrics of vegetable fiber, or silk. Therefore drapes, furniture covers, and other articles made entirely of these fabrics are not attacked. Moths will eat the woolen threads from woolen-cotton, woolen-rayon, or similar mixed-fiber fabrics, and in doing so may cut some of the vegetable fibers, just as they will eat a few small holes in cotton pillow covers if the feathers within become badly moth-infested. Moths never cause injury in trunks or bureau drawers filled only with vegetable fabrics. In storing goods, pack together those things, like sheets, pillow cases, towels, and linen dresses, which need no protection from moths. Place woolens, furs, and animal products together in protected tight storage.

Emergency fumigation of trunks and closets. Often the contents of trunks and closets that have been packed a long time and have had no moth protection are found to be "alive with insects." Do not scatter the infested pieces about the room, basement, or attic floor while determining the extent of the injury, because to do so would give the moth worms a chance to spread about. While flake naphthalene and paradichlorobenzene, mentioned above, are excellent for protection during storage, they do not kill rapidly. To kill all the moths in a trunk or closet quickly, fumigate for 12 to 24 hours with carbon disulfide, a liquid fumigant that may be purchased in tin cans at drug or seed stores. To fumigate, place on the top shelf of the closet, or on top of the garments in the trunk, a pie tin, saucer, or other shallow dish, and pour into it the amount of carbon disulfide needed. The liquid evaporates, forming a heavier-than-air, bad-smelling gas. After pouring the liquid into the dish, quickly close the closet door and seal all the cracks about the door, including the keyhole. The door should be gasketed for best results. Trunks can be paper-lined if necessary.

The following dosages of carbon disulfide are effective and can be modified for closets of other sizes:

Closet, 3 by 8 by 8 feet.....	1½ pints.
Closet, 2 by 5 by 7 feet.....	¾ cup.
Closet, 4 by 5 by 7 feet.....	1½ cups.
Trunk, 21 by 20 by 42 inches.....	3 tablespoonfuls.
Box, 1 by 2 by 2 feet.....	1 tablespoonful.

Liquid carbon disulfide is inflammable, and a mixture of the vapor with air is explosive. Keep lighted cigarettes or fire in any form away during the fumigation period. Do not turn light switches on or off in a room where carbon disulfide vapor is present. If vapor is escaping from the fumigated area into a room, open the windows slightly.

The United States Department of Agriculture does not recommend the fumigation of large spaces, such as homes, with carbon disulfide because of the fire hazard, but for trunks and closets, where only a small quantity of gas is involved, fumigation can be conducted by anyone exercising ordinary caution. Ethylene dichloride-carbon tetrachloride mixture is used in the same way. Upon evaporation, it produces a gas that is noninflammable and nonexplosive, and therefore free from the fire hazard. Unfortunately it is not so readily available at stores.

An ideal mothproof material should render the fabric resistant to all types of moths in the grub form, and also be obnoxious to the moth, thus preventing the laying of eggs. It should be colorless, odorless, inexpensive, easy to apply, and permanent to dry cleaning and laundering; it should in no way injure the material; and it should not be poisonous to human beings.

One of the materials first used for permanent mothproofing of wool was sodium silicofluoride. This material has not proved to be permanent to laundering and dry cleaning. The Eulan type of organic substances is the most successful of all substances used. This group has a definite affinity for the fibers and is not removed by washing or dry cleaning. Eulan N, a colorless acid dye, is applied the same as any acid color. It has a strong affinity for the fiber and renders the material absolutely immune to the attack of moths. This finish is fast to light, to washing, and to dry cleaning. Fabrics, such as carpets, that cannot be boiled must be treated with a different sub-

stance, such as Eulan N. K. This can be used as a spray. However, these materials are expensive and are not manufactured in the United States.

Suggestions for the Laboratory

Test the city water for temporary and permanent hardness.

Purchase various kinds of laundry soaps and determine the presence of free alkali in the dry soap and in a soap solution.

Determine the effect of the various types of soap upon textile fabrics. Compare the texture and size of the fabrics before and after laundering.

REFERENCES FOR ADDITIONAL STUDY

Bulletin Service National Association of Dyeing and Drycleaning, Inc.

Mitchell, Henry N., "Carpet Beetle Control Unsolved Wool Problem," *Textile World*, Vol. 96, No. 11 (1946), p. 170.

Warwicke, J., "Notes on Soap and Some Modern Detergents," *Textile Colorist*, Vol. 56, No. 1 (1939), pp. 215-378.

Appendix

Class Problems

A report from current literature should be made for each unit and for each problem, if time permits.

ADDITIONAL SUGGESTIONS FOR THE LABORATORY

SECTION I. TEXTILE CONSTRUCTION, PROCESSING, AND DESIGN

UNIT ONE. HOW FABRICS ARE CONSTRUCTED

1. Construct specimens of the three fundamental weaves, using heavy yarns of contrasting color for warp and for filling.
2. Construct specimens of the different kinds of weft knitting.

UNIT THREE. HOW PROCESSING ALTERS AND REFINES CLOTH

1. Weigh a specimen of heavily weighted cotton fabric. Determine the amount of starch or other sizing that can be rubbed out; that can be washed out. What percentage of the total weight of the cloth was added in the processing?
2. From an assortment of unlabeled materials select specimens of gray goods and the materials that could be made from them.

UNIT FOUR. HOW DYES ARE APPLIED TO TEXTILES

1. Determine the effect of hydrogen peroxide on cotton dyes of various hues. What is the effect of a solution of sodium hydrosulfite on these dyes?

UNIT FIVE. HOW DESIGN IS OBTAINED IN FABRICS

1. Choose several fabrics in which the serviceability of the cloth has not been adversely affected by the design used. Explain the basis of your decision.

2. Make a design for block printing on a linoleum block and print a curtain or a scarf.
3. Cut a stencil of a simple design and apply it to cloth.
4. Make a decorative handkerchief or small scarf by the tie-and-dye method or by batik.
5. Collect and arrange a departmental exhibit presenting the various means by which design is produced on cloth.

SECTION II. THE TEXTILE FIBERS

UNIT ONE. TEXTILE FIBERS: THEIR CLASSIFICATION AND ESSENTIAL PROPERTIES

1. Examine many types of fabrics and identify the fibers they contain, using the information given in Skinkle's tests as shown in the list of reagents and tests, and in the chart on page 581.

IDENTIFICATION OF THE TEXTILE FIBERS

REAGENTS AND TESTS ¹

1. *Flame*

Remove several fibers from the sample and hold the ends in the flame of a match.

2. *Bunsen flame test*

Hold the ends of the fibers in the flame of a Bunsen or Tirrell burner for 15-30 seconds or until the fibers are a bright red color.

3. *Five per cent KOH or NaOH test*

To prepare the reagent, dissolve 5 grams of potassium hydroxide or sodium hydroxide in water and make it up to 100 cc. Place a small bundle of fibers on a watchglass and add several cubic centimeters of the reagent. Place on wire gauze and heat to boiling; allow the sample to boil for 5-10 minutes.

¹ John H. Skinkle, "Identification of the Fibers," *Rayon Textile Monthly*, Vol. 21, No. 8 (1940), pp. 38-39.

CHEMICAL IDENTIFICATION OF FIBERS ¹

Hold Fibers in Flame (1)

Do not burn Asbestos Glass	Burn, ash retains shape of fiber Weighted Silk	Fibers burn or melt to ball Boil in 5% KOH or NaOH (3)				
		Hold Fibers in Flame (1)				
		Test with acetone at room temperature (6)				
Heat in Bunsen flame (2)	Soluble Silks, Hairs, Casein Test with cold, conc. HCL (4)	Insoluble				
		Test with acetone at room temperature (6)				
		Test with acetone at room temperature (6)				
Melt Glass	Do not melt Asbestos	Soluble Silk Tussah	Insoluble Hairs, Casein Test with 20% NaOH at 30° C for 3 hours (5)	Soluble		
				Acetate, Vinyl		
				Test with cold glacial acetic acid (7)		
		Soluble Hairs	Insoluble Casein	Soluble Acetate	Insoluble Vinyl	Strip dye, test with ZnCl ₂ -I ₂ (9)
						Blue Color Mercerized, Cupra Viscose, Cisalfa
						No Color Cotton, Flax, Jute, Ramie, Hemp
						If undyed, test with aniline sul- fate (11)
						If undyed, test with Millon's re- agent (10)
						Red Color Cisalfa
						No Color Merc. Cupra Viscose
						Yellow Color Jute Hemp
						No Color Cotton Flax Ramie

¹ John H. Skinkle, "Identification of the Fibers," *Rayon Textile Monthly*, Vol. 21, No. 8 (1940), p. 37.

4. *Gold concentrated HCl test*

Use ordinary concentrated hydrochloric acid at room temperature.

Place a small bundle of fibers on a watchglass and add several cubic centimeters of hydrochloric acid. Allow the samples to remain for 5–10 minutes.

5. *Twenty per cent NaOH test*

Dissolve 20 grams of sodium hydroxide in 80 cc. of water. Heat a beaker of water to 30° C. (86° F.). Place about 5 cc. of the reagent in a test tube, add a small bundle of the fibers, and stand the test tube in the beaker of water. Maintain the water at 30° C. for 3 hours.

6. *Acetone test*

Place a few fibers on a watchglass and add several cubic centimeters of acetone at room temperature for 10–15 minutes.

7. *Glacial acetic acid test*

Place a few fibers on a watchglass and add several cubic centimeters of glacial (100 per cent) acetic acid at room temperature for 10–15 minutes.

8. *Phenol test*

In a test tube or small beaker, melt enough phenol (carbolic acid) to give about 5 cc. of liquid. Phenol melts at about 40° C. (104° F.). Caution should be used to prevent spattering and to prevent the phenol from contacting the skin or bad burns may be suffered.

Place a small bundle of the fibers in the melted phenol and allow them to remain 10–15 minutes.

9. *ZnCl₂-I₂ test*

This color test may be used on dyed fibers by stripping the dye off the fibers first.

Solution A: Dissolve 280 grams of zinc chloride in 300 cc. of water.

Solution B: Dissolve 20 grams of potassium iodide in 100 cc. of water and then dissolve 1 gram of iodine.

When ready to make a test, place 20 cc. of Solution A in a small beaker or test tube and add 0.2 cc. of Solution B. Place

a bundle of the fibers and a small piece of cotton cloth or yarn in the mixture and allow it to stand at room temperature for exactly 3 minutes. If the cotton is still white, observe the color of the unknown; if the cotton is darkened, rinse both the unknown and the cotton together with water until the cotton turns white; then observe the color of the unknown.

10. *Millon's reagent test*

This test may be applied only to undyed samples.

The reagent is prepared by placing 1 cc. of metallic mercury in a small beaker, adding 10 cc. of concentrated nitric acid, and warming if necessary to dissolve the mercury. When the mercury is dissolved, add 10 cc. of water. This reagent should not be kept for over a month.

A few fibers are placed on a watchglass and several drops of the reagent are added. The watchglass is then heated until boiling begins and the color of the specimen is noted.

11. *Aniline sulfate test*

Dissolve 2 grams of aniline sulfate in 100 cc. of water.

A small bundle of fibers is placed on a watchglass and several drops of reagent are added at room temperature. The color of the unknown is observed.

This test also can be used only on undyed samples.

UNIT TWO. WOOL AND OTHER HAIR FIBERS

1. List five uses of wool goods common fifty years ago which have been discontinued. What explanation can you give?
2. From descriptions in literature or magazines list six fabrics that were in common use fifty years ago. How many of these may be obtained on the market today? Make a similar study of the fabrics used fifteen years ago. Compare the weight, method of construction, color, and design of these materials.
3. Obtain fabrics of all-wool and blends and compare their texture and appearance.

UNIT THREE. THE QUEEN OF FABRICS

1. Burn specimens of various kinds of silk fabrics, making note of the form and amount of the ash.

UNIT FOUR. COTTON AND OTHER SEED HAIRS

1. Secure cotton bolls. Try separating cotton from the seed by hand; then use a small comb as an improvised hand gin. Examine fibers from a single boll, determining relative length and fineness.
2. Make a serigraph of each of three sizes of cotton yarns and compare their breaking strength. A simple method of preparing these specimens is to wrap eighty strands of thread onto a piece of cardboard, in parallel order but not overlapping. Fasten these securely with gummed stickers which are placed three inches apart. It will be necessary to place a sticker under the threads and cover this one with another on top of the threads. If large stickers are used they can be cut through the centers. Break the specimen thus prepared in the testing machine, clamping the stickers in the jaws of the machine.
3. Test the breaking strength of specimens of fabric and record findings. Expose the material to direct sunlight or in the Fadeometer for a definite period of time. Test exposed material for loss in strength.
4. Treat unsized cotton material with concentrated alkali for a short time; rinse thoroughly. Hold under tension if possible while rinsing. Compare with the original specimen for shrinkage and increase in tensile strength. Examine both treated and untreated under high magnification.

UNIT FIVE. LINEN AND OTHER BAST AND LEAF FIBERS

1. Arrange in order of quality a laboratory set of linen fabrics of various kinds. Check your results with the key list.
2. Make the following tests on linen and cotton fabrics and compare your observations with those on which the tests were based.
 - A. Absorptive tests. With a medicine dropper place one drop of oil or ink on each fabric and observe its spread.
 - B. Tear cotton and linen fabrics and compare the torn ends of the yarns.

- C. Untwist the yarns and compare the arrangement of the fibers.
- D. Burn cotton and linen yarns and observe the difference in the charred ends.

UNIT SIX. SYNTHETIC FIBERS: SCIENCE IN COMPETITION
WITH NATURE

1. Arrange according to the fibers used a laboratory set of unlabeled fabrics including some all silk, all rayon, and a combination of rayon and other fibers. Check with the key list.
2. Examine samples of available synthetic fabrics constructed from filament yarns to determine the type of weave, yarn, and finish commonly used.
3. Examine samples of available fabrics made from staple fibers to determine the type of yarn and kinds of fibers present.
4. If possible obtain fabrics made from nylon, vinyon, casein, and other synthetic fibers. Make comparisons within this group and with other synthetic and natural fibers.

SECTION III. TEXTILES AND THE CONSUMER

UNIT ONE. THE CONSUMER AND THE TEXTILE MARKET

1. Examine tariff rates of standard types of clothing fabrics, as wool suitings, linens, fine cottons, etc. (Secure a copy of the tariff law from Superintendent of Documents, Washington, D. C.)
2. What is the National Consumers' League? Give a report covering its influence on the government trade.
3. Secure facts concerning the legal standards for employment of women and children in your state. (Secure material from the Labor Department at State Capitol.) Compare these with standards recommended by the Department of Labor, Washington, D. C.
4. Prepare a list of all the hats you purchased during the year. What type of material and form of decoration was used? Why do people purchase new hats? Why did you?

5. Report on work of the United States Bureau of Standards in regard to standardization products for federal government purchasing.
6. Report on program of Consumers' Research, Inc., Washington, N. J. (a membership organization that tests retail goods and makes recommendations to its members).
7. Examine advertisements in magazines and papers. What information was given in each? What type of labeling was used?

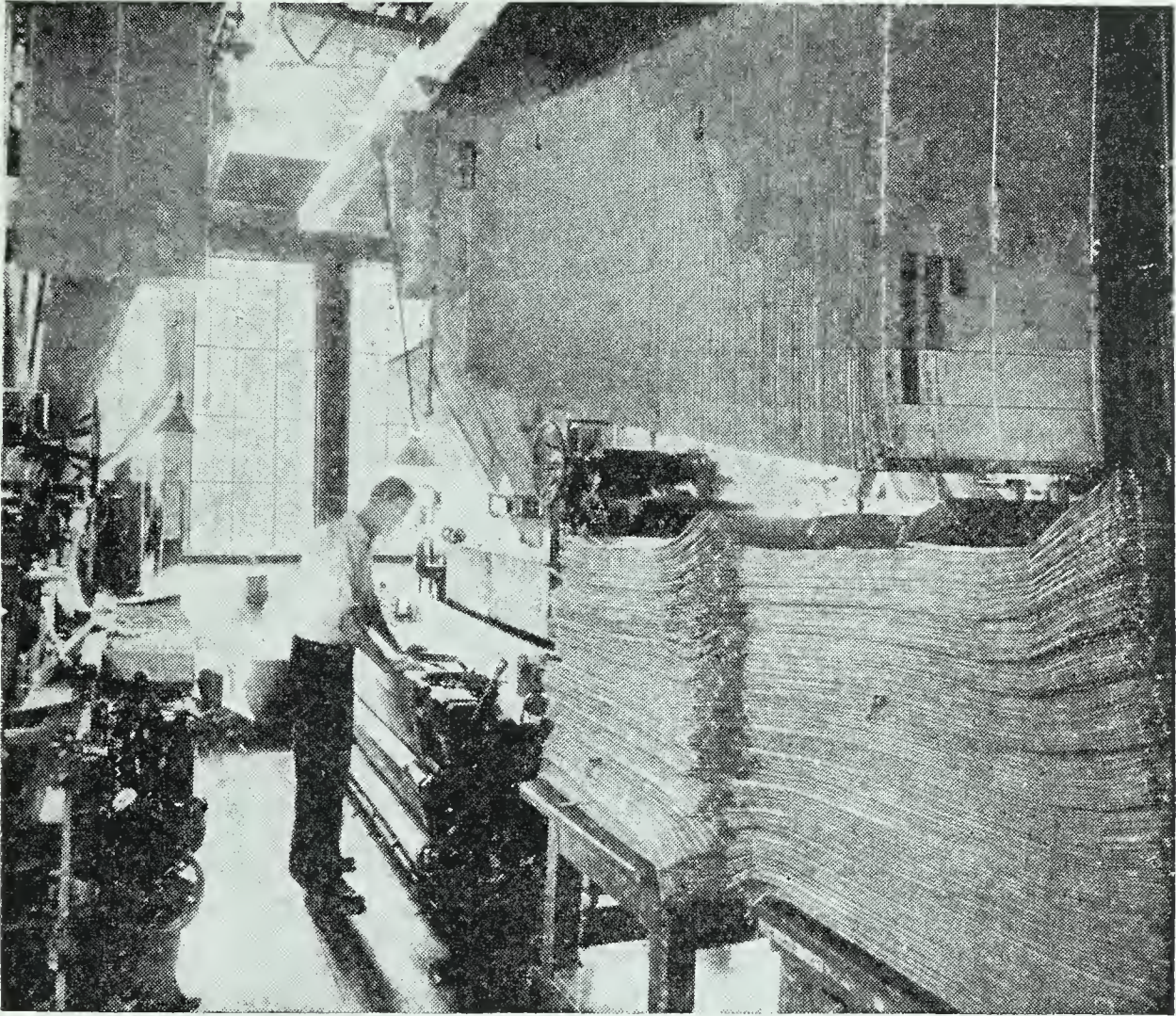
.UNIT TWO. HOW TO SELECT FABRICS FOR CLOTHING
AND HOUSEHOLD USE

1. Each student contribute a list of all fabrics used at home (aside from clothing), indicating name of fabric, purpose, quantity, etc. Let a committee of the class assemble the data in total quantities per home.
2. Arrange set of laboratory swatches of curtain material according to (a) fiber, (b) practicability, (c) probable cost. Check with key list.
3. Examine several blankets for weight, fiber, thickness, texture, etc.
4. Examine available samples of carpets to determine the type of structure and quality.
5. Make a field trip, as a class, to the carpet department of a retail store.

Jacquard Machines

In order to weave elaborate designs, a Jacquard machine is required. By means of the Jacquard, each warp yarn may be controlled as desired (see page 587). This attachment, often spoken of as the Jacquard loom, was invented by a Frenchman, Joseph Marie Jacquard, in 1801. Its capacity varies from 200 to 300, 1,000, or even more warp yarns.

In the operation of a Jacquard, each warp is drawn through a heddle eye as in other weaving. However, the heddle in a



Courtesy *Textile World*

Jacquard loom; 28,500 cards are required for one pattern.

Jacquard consists of a metal eye attached to a specially treated cord, as shown in the illustration on page 588.

Where the pattern is repeated across the width of the cloth, the leashes carrying the corresponding warp yarns are attached to a single long neck cord, as shown on page 589. Needles in the upper part of the loom work horizontally and are pressed forward against a card by means of a spring. Each neck cord, attached to a separate rod, passes through the eye of its horizontal needle. The upper ends of these rods are in the form of hooks which rest over a series of bars called a griffe. (See the illustration on page 589.)

If a card containing a hole for every horizontal needle was brought into position by the cylinder each rod would remain in place and would be raised automatically. The lifting of all

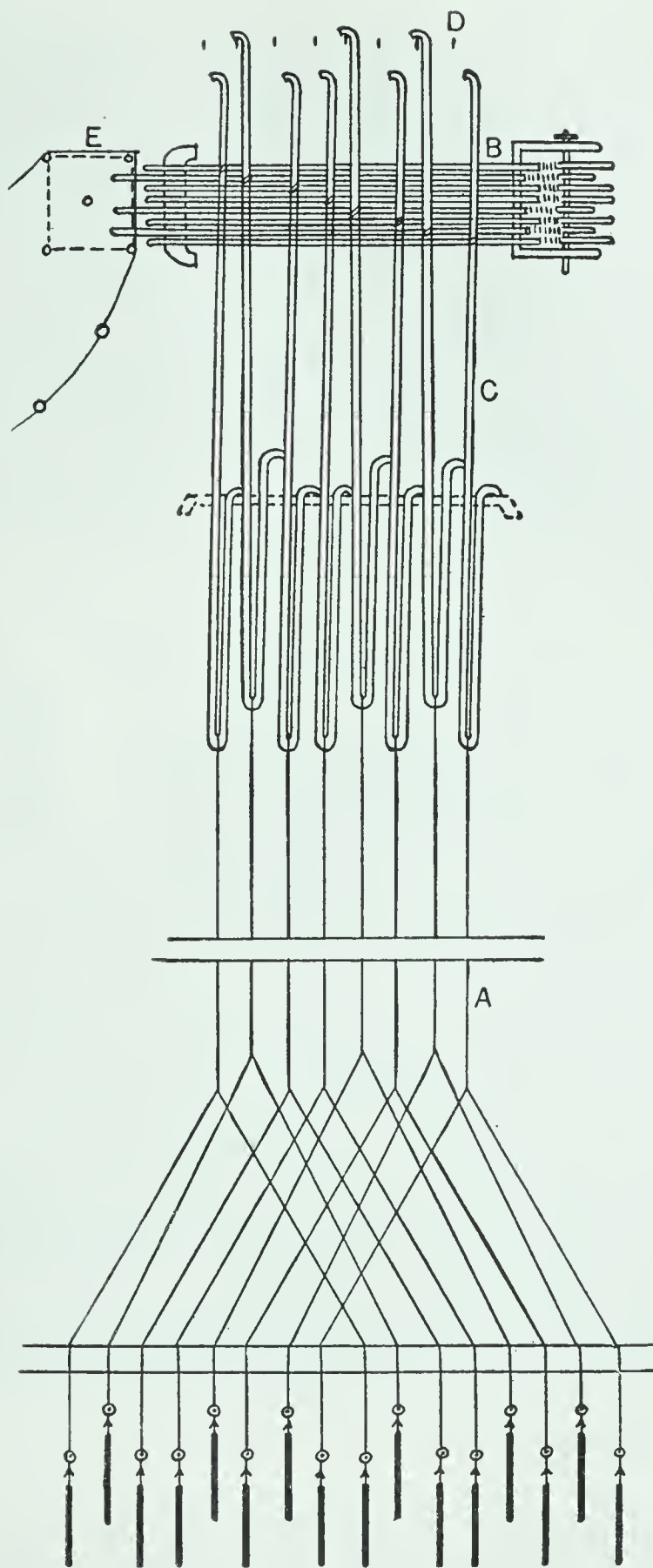


Jacquard heddles. Metal eyes shown at top.

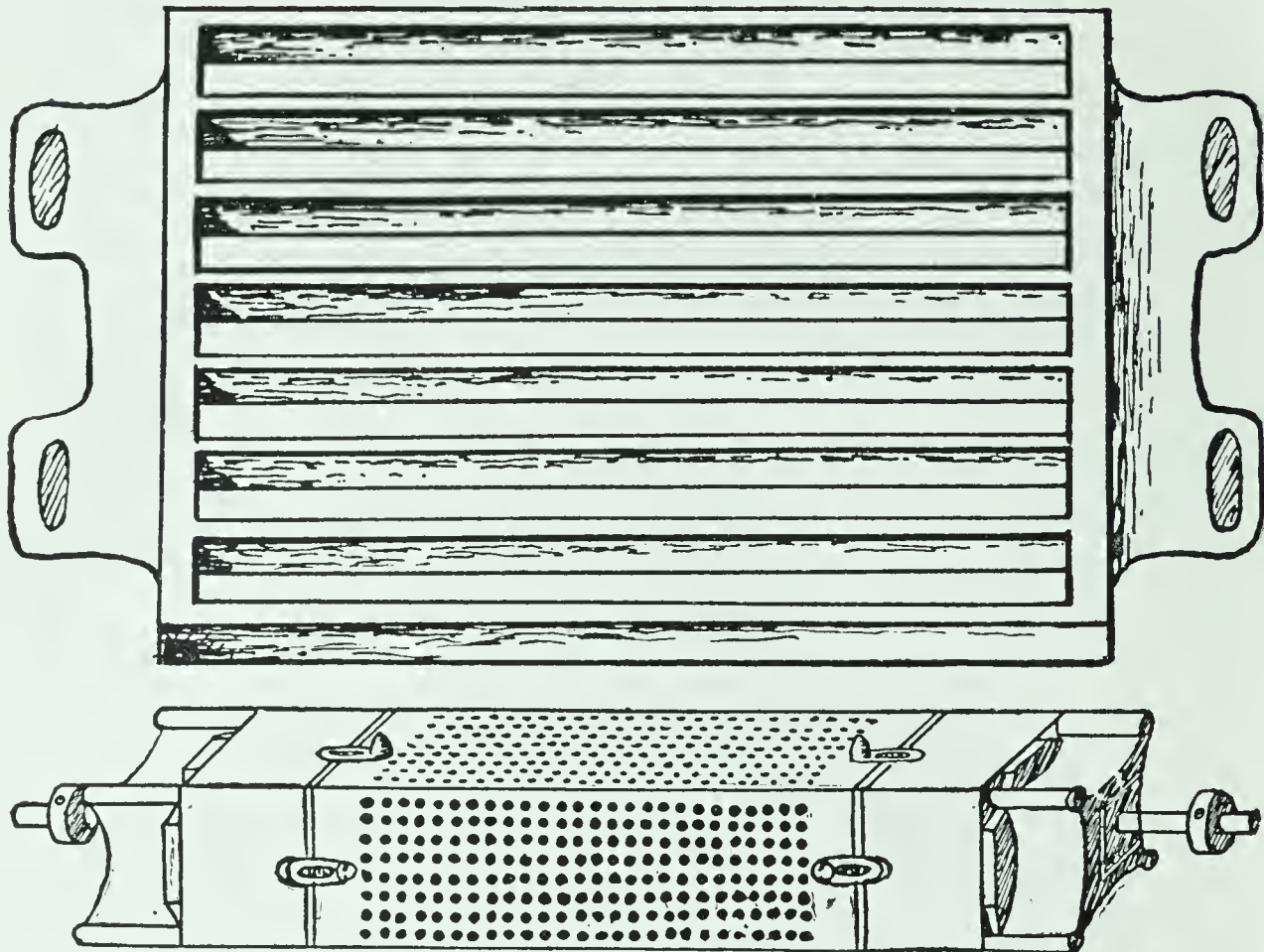
the warp prevents the formation of a shed. In preparing a design for a Jacquard, after the pattern has been worked out on point draft paper, a card is prepared for each filling yarn in one repeat of the design. (See page 590.) The first card is punched with rows of holes, each of which corresponds to a warp yarn which must be raised and made to appear on the surface of the fabric for the first interlacing of the filling. The second one is punched to correspond with the warp yarns to be raised, which therefore appear on the surface of the fabric for the second interlacing of the filling. Thus a card is prepared for each filling yarn in one repeat of the pattern or design. These cards are laced together in order into an endless chain and placed in a frame over the loom. (See page 591.) Both the Jacquard cards and the Jacquard machines are referred to as of a certain index, depending upon the number of warp yarns for which they are planned and the resulting size of the card.

A machine handling 1,200 warp yarns will have a denser construction than one handling 200 warp yarns, and consequently the needles are placed much closer together. The card to fit this machine must have smaller, more closely punched holes. Both the card and the machine are referred to as having a fine index. Tapestry cards are necessarily of fine index since there must be at least sixteen holes in a row. Machines handling only 200 to 800 warp yarns generally use a coarse index card.

As cards are brought into place they push back the horizontal needles for which there are no holes. The rigid rods are tripped off the griffe and lowered, thus forming a shed. The illustration on page 589 shows hooks 2, 5, and 7 raised with the

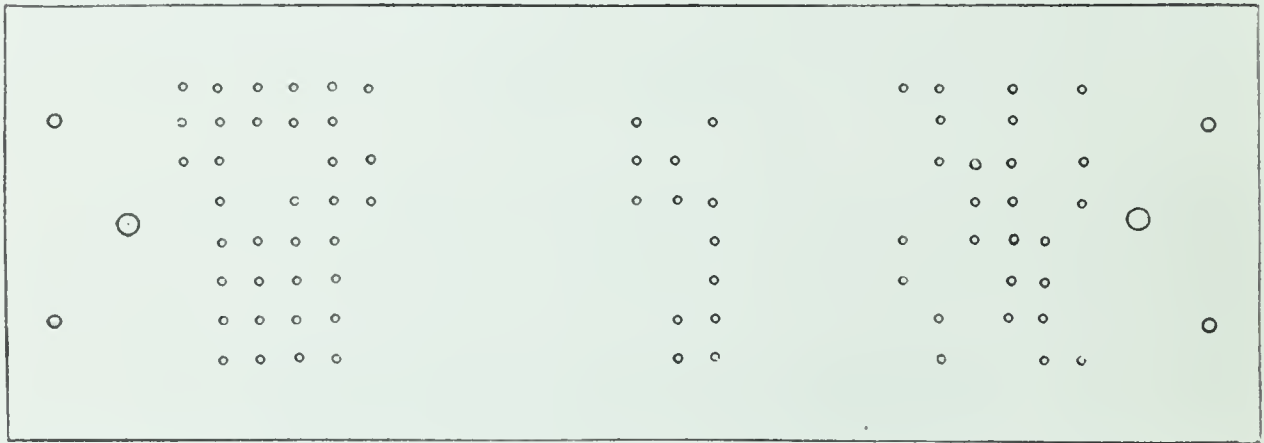


Working drawing of Jacquard. A, long-neck cords; B, horizontal needles; C, rigid rods; D, cross section of gripper bar; E, cross section of cylinder.



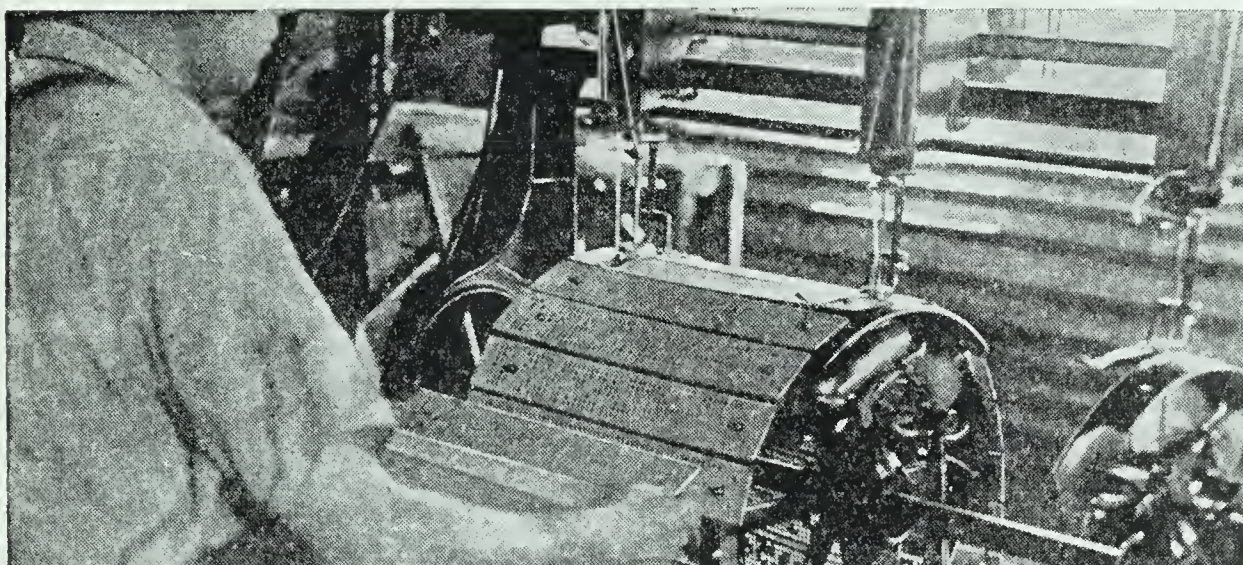
Courtesy Posselt's *Technology of Textile Design*, published by McGraw-Hill Book Co., Inc.

Top, top view of the griffe, the section of the different bars of which is shown on D, page 589. Bottom, cylinder around which the cards work.



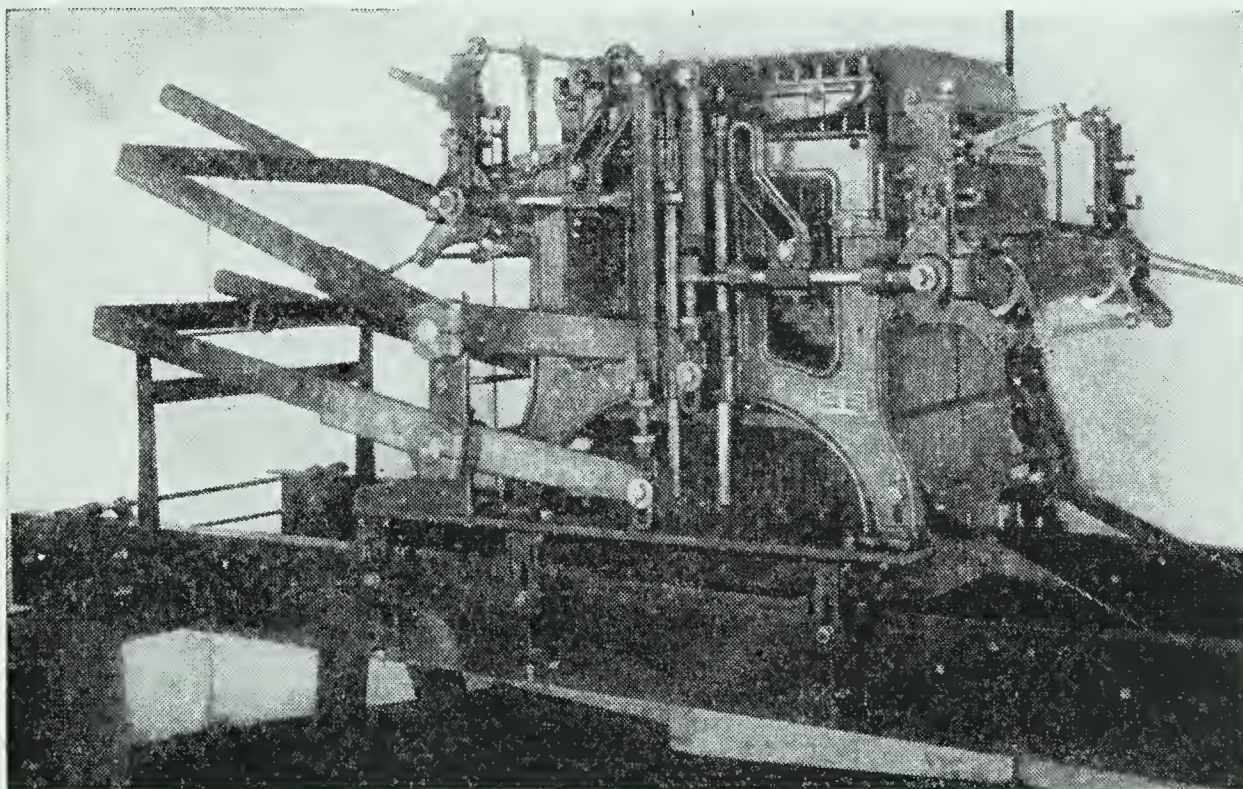
Drawing of Jacquard card.

griffe, and hooks 1, 3, 4, 6, and 8 tripped off. Thus it can be seen that the perforated cards, by permitting the passing of certain needles and the raising of the hooks to which the long cords are attached, govern the position of the individual warp yarns and, in this manner, develop the pattern.



Courtesy Zion Lace Industries, Marshall Field and Co.

Lacing the Jacquard cards for the lace machines according to the desired pattern. These cards control the making of the pattern.



A modern Jacquard.

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