Textile Terminology

Textile : [illegible]

Fibres : [illegible]

There are two types of fibres

1. Filaments
2. Staple fibres

1. Filaments

Filaments are natural or man-made fibres of continuous length measurable in yards or meters. For e.g. silk and all man made fibres.

Filament fibres are two types i.e. monofilament and multifilament.

Mono filaments

Monofilaments are made of a single strand which is strong and smooth.

Multifilament

Multifilament yarns are composed of a number of tiny filaments twisted together.

Staple fibres

They are short in length and measurable in inches. Length varies between three quarter of inch to 18 inches or so, For e.g. All the natural fibres except silk are staple fibre. However manmade fibres if cut into short length they are also known as staple fibre.

Yarn

Yarn is made by twisting the groups of fibre together.

Yarn is the basic assemblage of fibres or filaments which are bund together by twist.

Twist

Twist is the number of spiral turns given to a yarn in order to hold the constituent of fibres together. If the twist follows the direction of control portion of letter S then it is known as S-twist. If the centre portion of Z is followed, it is Z twist.

Fabric

Fabric is the cloth produced by knitting, weaving and felting.

Weaving

Interlacing of two sets of yarns is weaving which interlace at right angles to each other.

Warp set

Lengthwise yarn/ends.

Weft set

Widthwise yarn/crosswise yarn/picks/filling yarns.

Selvedge

Selvedge is the side line of the fabric.

Non woven

All those fabrics which are manufactured without weaving are known as non-woven fabrics for e.g. FELT.

Knitting

The yarn is bound around a needle to form the loops which forms one row. This row of loops is caught by another row of loops and so on, till the continuous length of cloth is made. It may be done by hand or by machine.

Spinning

Spinning is the joining of short fibres by drawing them from a loose fibre mass and twisting them together.

Thread count

Known as fabric count. It is the number of warp and waft threads per square inch of fabric.

Grain

Grain is the direction of yarn. When a pattern refers to lengthwise grain of a fabric, it means, the direction of warp thread. The cross wise grains means the filling end.

Fibre Identification

Identification of fibre content in fabrics has difficult for average consumer as well as experienced merchants because of growing variety of fibres, blending techniques in yarns and fabric construction. Yet the fibre content is of great importance to the consumer to check the information of labels. There are four simple methods used for fibre identification.

1. Visual test
2. Burning test
3. Microscopic test
4. Solubility test

Visual test

The fibre is tested by appearance and hand or touch of the fabrics e.g. wool fabrics feel warm to the touch and vegetable fibres – i.e. cotton, linen feel cool to touch.

Burning test

It gives a clue to fibre type, that is, whether natural or man made. We can observe the fibre according to how it burns (rapidly, slowly), how it smells and the ash content (colour & shape).

Microscopic test

Microscopic test may help to conform burning test. This test is used to study the surface characteristics of yarn and fabircs. Each natural fibre has its own distinctive structural shape & markings that facilitate the identification of fibre. Whereas man made fibres are difficult to identify because they are very similar in appearance.

Solubility test

Solubility tests are particularly necessary when we want to separate the individual fibres used in a blend. This test is valuable to determine the fibre content of an unknown fabric and verify other test. Different solvents are used to distinguish one fibre from other.

These tests are helpful both for fabric manufactures and consumers to check the information on labels whether it is true or not. The average consumer can use visual test, burning test and simple solubility test to identify the fibre.

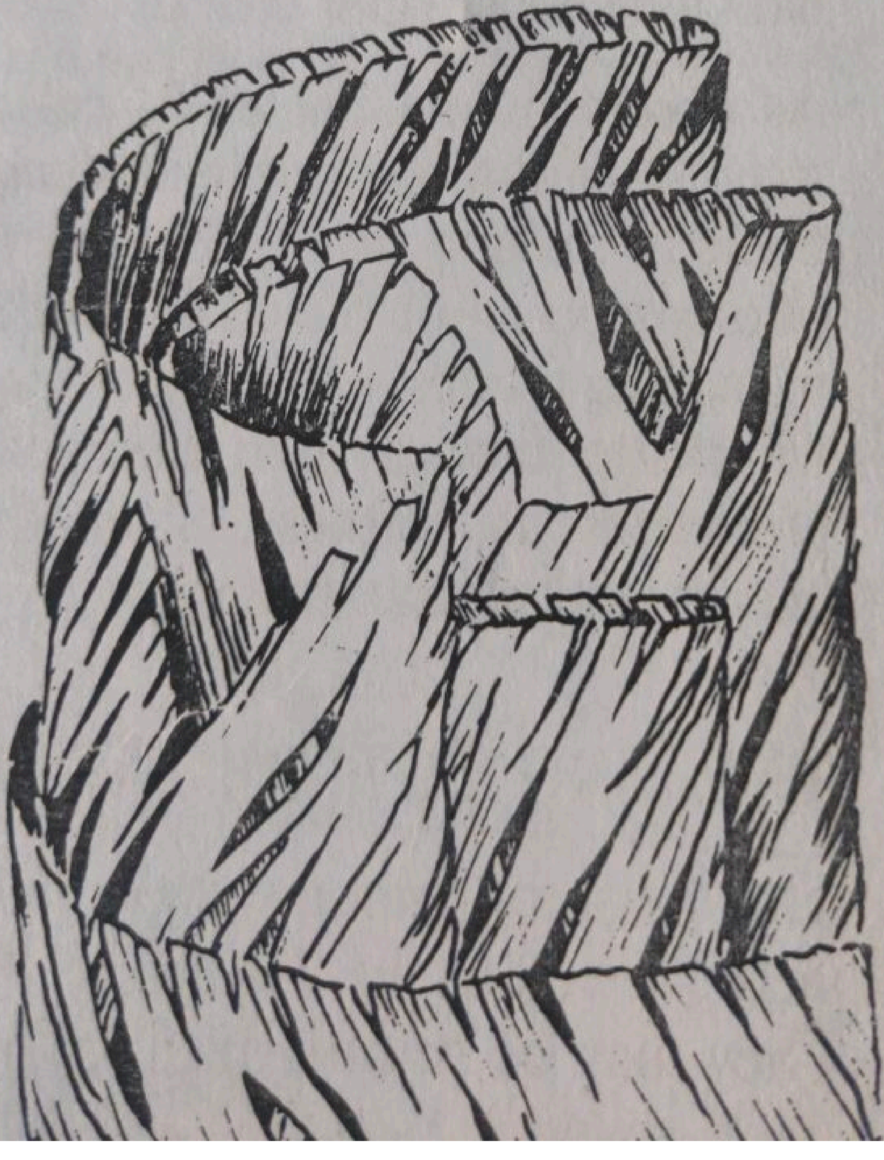
TABLE 1-1 ***CLASSIFICATION OF FIBERS***

TYPE	NAME OF FIBER	SOURCE OR COMPOSITION
Natural Fibers:		
Vegetable	Cotton	Cotton boll (cellulose)
	Linen	Flax stalk (cellulose)
	Jute	Jute stalk (cellulose)
	Hemp	Hemp or abaca stalk (cellulose)
	Sisal	Agave leaf (cellulose)
	Kapok	Kapok tree (cellulose)
	Ramie	Rhea or China grass (cellulose)
	Coir	Coconut husk (cellulose)
	Piña	Pineapple leaf (cellulose)
Animal	Wool	Sheep (protein)
	Silk	Silkworms (protein)
	Hair	Hair-bearing animals (protein)
Mineral	Asbestos	Varieties of rock (silicate of magnesium and calcium)
Manmade Fibers:		
Cellulosic	Rayon	Cotton linters or wood
	Acetate	Cotton linters or wood
	Triacetate	Cotton linters or wood
Noncellulosic Polymers	Nylon	Aliphatic polyamide
	Aramid	Aromatic polyamide
	Polyester	Dihydric alcohol and terephthalic acid
	Acrylic	Acrylonitrile (at least 85%)
	Modacrylic	Acrylonitrile (35–84%)
	Spandex	Polyurethane (at least 85%)
	Olefin	Ethylene or propylene (at least 85%)
	Vinyon	Vinyl chloride (at least 85%)
	Saran	Vinylidene chloride (at least 80%)
	Novoloid	Phenol based novalac
	Polycarbonate	Carbonic acid (polyester derivative)
	Polybenzimidazole	Tetraminobiphenyl and diphenyl isophthalate
	Alginate	Calcium alginate
	Fluorocarbon	Tetrafluoroethylene
	Graft	Molecular graft of polymers
	Matrix	Mixture of polymers
	Anidex*	Monohydric alcohol and acrylic acid
	Lastrile*	Acrylonitrile (10–50%) and a diene
	Nytril*	Vinylidene dinitrile (at least 85%)
	Vinal*	Vinyl alcohol (at least 50%)
Protein	Azlon*	Corn, soybean, etc.
Rubber	Rubber	Natural or synthetic rubber
Metallic	Metal	Aluminum, silver, gold, stainless steel
Mineral	Glass	Silica sand, limestone, other minerals
	Ceramic	Alumina, silica
	Graphite	Carbon

* Not presently commercially available in United States; not covered in text.

of consumers' goods.

Strength. Strength of a fiber is indicated by the ability to resist being pulled or torn apart when subjected to stress or tension. Cotton fiber is relatively strong due to the intrinsic structure of layers of criss-crossed, minute, spiraled fibrils that compose the fiber cell (see Figure 13-4). Strength is also determined by the character of the cotton yarns, which should be of



long staple and tightly twisted. Compact construction, represented by high thread count, helps a fabric keep its shape and give longer wear. A sample of the fabric may be tested for strength by holding it in both hands and pressing down firmly with the thumbs while pulling. If the cloth gives easily, it will not stand the strain of wear. Strength can be substantially improved by mercerizing or ammoniating.

Elasticity. Elasticity refers to the extent to which a fiber can be elongated by stretching and then returning to its former condition of size or length. Cotton fiber has very little natural elasticity. This characteristic can be altered to varying extents by hard-twisting fibers into creped yarns and by using fabric construction techniques such as knitting. The slack mercerization technique may be used to give cotton fabrics some stretch in the warp and/or filling, thereby reducing the binding characteristic of the cotton fabrics.

Resilience. Resilience refers to the extent to which a fabric can be deformed by compression or crushing and return to its original condition. The tendency of cotton fabrics to wrinkle easily may be offset by finishing processes that give a wrinkle-resistant quality.

Drapability. The ability of a fabric to hang easily and fall into graceful shape and folds indicates its drapability. The characteristic is dependent upon the kind of fiber, yarn, and construction of the fabric as well as finish given to it. Cotton does not intrinsically have the body and suppleness required for good drapability. However, the nature and compactness of the fabric construction can improve it. This can be enhanced further by sizing and other finishes.

Heat Conductivity. The extent to which heat can be conveyed through a fiber or a fabric indicates its heat conductivity. Cotton has a relatively high degree of heat conductivity. Therefore it is, basically, a cool fiber. Cotton can be made into excellent summer clothing because it is a good conductor of heat. Crisp, clean, lightweight cotton fabrics look cool as well as feel cool. When warmth is required, cotton yarn made into napped or pile weave fabrics will have decreased heat conductivity, particularly if the fabric is compactly constructed.

Absorbency. The ease and extent to which moisture can penetrate into a fiber determines its absorbency. Once the outer protective cuticle of the cotton fiber is broken down by finishing processes, such as kiering and mercerizing, the fiber becomes very absorbent. Cotton fiber is composed primarily of cellulose, which is very absorbent. Its hollow center, or lumen, aids in conveying moisture. Such factors as the amount of twist in the yarn will also affect the absorbency, since a low-twisted yarn will be more absorbent than a high-twisted one. Fabric structure, such as a pile weave, will affect absorbency. Also, the compactness of the weave influences the absorbency because the looser the structure the more absorbent the fabric will be.

Cleanliness and Washability. Although cotton attracts dirt particles because of its roughness, this disadvantage is offset by the washability of the fiber. Cotton fabrics are not injured even in very hot water with strong soaps or detergents; they launder well and withstand rough handling.

Reaction to Bleaches. As discussed in Chapter 9, bleaches are chemical solutions designed to remove discoloration (and sometimes color). While hydrogen peroxide may be used, the more common household bleaches for cotton are solutions of sodium hypochlorite, such as Clorox, or sodium perborate, such as Snowy, which is a milder type. These bleaches, used as directed, will effectively bleach cotton fabrics. Bleach should be put into the rinse water after washing so that it is thoroughly mixed and diluted to avoid the oxidizing or yellowing that may be caused by overconcentration. Labels on wash-and-wear fabrics should be observed since some of these finishes are chlorine retentive—they turn yellow when subjected to sodium hypochlorite bleaches.

Shrinkage. When cotton fiber is wet, it tends to contract or shrink as it dries. As a result, cotton yarns and fabrics can shrink considerably, particularly those that are loosely constructed. However, preshrinking finishing processes, such as discussed in Chapter 9, minimize shrinkage in cotton fabrics. Labels should be read for the amount of residual shrinkage that a fabric or garment has and care instructions should be followed to retain the required size and shape.

Effect of Heat. Cotton will withstand moderate heat. If pressed with an iron that is too hot or if a hot iron is allowed to remain too long in one place on the fabric, it will scorch and ultimately burn. It is therefore best to either iron cotton material that has been dampened or use a steam iron.

Effect of Light. Cotton fiber oxidizes, turning yellow and losing strength from exposure to sunlight over a protracted period of time. Cotton fabrics should therefore be shaded from direct sunlight.

Resistance to Mildew. Cotton fabrics, especially sized fabrics, mildew readily when permitted to remain in a damp condition. Small greenish-black or rust colored spots caused by mildew fungus develop and a musty odor may be detected. Therefore, cotton material should be kept in a dry atmosphere. Where this is not possible, a mildew resistant finish or a mildew inhibitor is advisable when stored.

Resistance to Insects. Cotton is not digestible by moth larvae, so the fabric will not be attacked by moths. But in fabrics containing cotton and wool, the larvae may damage the cotton to get at the wool. Certain other insects that may be attracted to its cellulose content may damage cotton, but this is not common.

Reaction to Alkalies. Cotton is not harmed by alkalies. In fact, a solution of sodium hydroxide is used to mercerize cotton, making it stronger, smoother, and more lustrous.

Reaction to Acids. Cotton is not damaged by such volatile organic acids as acetic acid (vinegar). However, it is tendered if such nonvolatile organic acids as oxalic and citric (found in orange, lemon, and grapefruit juices) are allowed to remain on it, particularly if heat is also applied. They should therefore be rinsed with cool water as soon as possible. Concentrated cold or diluted hot mineral acids, such as sulfuric acid, will destroy cotton.

Affinity for Dyes. Cotton has a good affinity for dyes. It is dyed best with vat dyes, but oxidation bases, azoic, and reactive dyes may also be effectively used. Colorfastness is generally good, but specific conditions should be considered (see

Table 11-1). Fastness of dye to washing can be tested by washing a sample in hot water. Fastness to light can be tested by exposing a sample to light for a week or more. Penetration or thoroughness of dye can be tested by raveling a yarn and examining its unexposed surfaces.

Resistance to Perspiration. Perspiration may be alkaline or acidic, depending upon the individual's metabolism. Since cotton is resistant to alkali, alkali perspiration does not deteriorate cotton. However, acid perspiration has a slightly deteriorat-

REVIEW QUESTIONS

1. (a) What are the byproducts of the cotton plant? (b) For what are they used?
2. How would you judge cotton fabrics?
3. Name the more important varieties of

1 Introduction to fibre polymers and fibre properties

... 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 what ever substance it be out of which, the silkworm wire-draws his clew... This hint ... may give some ingenious inquisitive person an occasion of making some trials, which if successful ... I suppose he will have no occasion to be displeased.

This speculation on making a filament was written in 1664 by the English physicist Dr Robert Hooke in his book *Micrographica*. His speculation became a reality from 1900 onward. It became a reality because of the continuing scientific investigations being carried out on natural and man-made fibres and similar materials. These investigations have yielded a steadily increasing understanding of fibre composition, structure, properties and behaviour, and have enabled the large-scale manufacture of fibres not found in nature, i.e. man-made fibres. The knowledge and understanding gained from manufacturing fibres, as distinct from growing them, has assisted in increasing the understanding of the very complex molecular or polymer composition of the natural fibres. Even though very much more is now known about fibres, there are still many unanswered questions about their properties and behaviour. Some of the answers will, no doubt, be provided in the years to come.

In the meantime, in order to understand some of the reasons why a fibre possesses certain properties and behaves in a particular manner when in use, it is necessary to acquire a knowledge of the following properties.

Polymerisation

Textile fibres, like most substances, are made up of molecules. Fibre molecules are called **polymers** (derived from the Latin *poly* = many and *mer* = unit). The 'unit' of a polymer is the **monomer**, also derived from the Latin (*mono* = one). At the molecular level the polymer is extremely long and linear, whereas the monomer is very small. Monomers are usually chemically reactive, whereas polymers tend to be unreactive. This is illustrated by the chemical reaction called polymerisation, which causes the monomers to join end-to-end to form a polymer.

Although the polymer tends, in general, to be chemically unreactive, this does not prevent its being subsequently attacked by chemicals and other degrading agents.

The length of the polymer is most important. All fibres, both man-made and natural, have long to extremely long polymers. Measuring the length of a polymer is a complicated, if not impossible, task. Estimates of the length of a polymer can be obtained by determining its **degree of polymerisation**. This is often abbreviated to DP and defined by the following mathematical expression:

$$\text{degree of polymerisation} = \frac{\text{average molecular weight of polymer}}{\text{molecular weight of the repeating unit in the polymer}}$$

Note: Some fibre polymers may have been polymerised from two or more different monomers; thus, the repeating unit is the combination or segment formed by these two or more different monomers which repeat regularly along the length of the polymer.

In determining the degree of polymerisation of cotton, for instance, a figure of 5000 is obtained. This means that, on average, each cotton polymer consists of about 5000 repeating units. With cotton the repeating unit is **cellobiose**, which may also be taken as its monomer. Cotton provides an example to illustrate the size relationship between polymer and monomer. Imagine the cotton polymer to be as thick as an ordinary 8 mm pencil; the polymer would then be about 50 m long. As it consists on average of about 5000 repeating units or monomers, then each one of these would be about 10 mm long — a ratio of 5000:1.

A polymer is often described as having a **backbone**, consisting of the atoms which are bonded to each other in a linear configuration and which are responsible for the length of the polymer. This is illustrated in Table 1.2.

Although it is not yet known how cellulose and keratin are polymerised in nature, the polymerisation of man-made, synthetic monomers to polymers is quite well understood. The manufacture of the synthetic, polymeric material which will be extruded to form the synthetic, man-made filament is categorised into two types of polymerisation: addition and condensation polymerisation.

Addition polymerisation

With this type of polymerisation the monomers add or join end-to-end without liberating any by-product on polymerisation. Some fibres consisting of addition polymers are acrylic, modacrylic, polyethylene or polyethene, polypropylene or polypropene, polyvinyl alcohol and the chlorofibres, namely polyvinyl chloride and polyvinylidene chloride.

Condensation polymerisation

With this type of polymerisation the monomers join end-to-end and liberate a by-product. This by-product is usually a simple compound — generally water — but it may alternatively be hydrogen chloride or ammonia, depending upon the specific monomers involved. Some fibres consisting of condensation polymers are elastomeric, nylon and polyester.

Note: The polymers of acetate, cotton, flax, silk, triacetate, viscose and other regenerated cellulose fibres, and wool, do not fit readily into the above classification, because not enough is known as yet about the way their polymers are synthesised in nature.

A knowledge of addition and condensation polymerisation is of importance in the synthesis and large-scale manufacture of the textile polymeric substances and their extrusion as textile filaments. Such knowledge belongs more to chemical engineering technology than to textile technology. Similarly, a knowledge of the propagation, growth, nurturing and harvesting of natural fibres belongs more to the specialised agricultural sciences of animal husbandry and crop cultivation. The textile technologist recognises such knowledge as being peripheral and to be used for rounding off explanations and understanding of fibre properties and behaviour. Synthetic fibre polymers and their respective fibres are at times referred to by the appropriate name found in the categorisation below. It will be noted that the natural, regenerated and ester-cellulose fibres are not included. The reason is that insufficient is known about the growth, formation and/or synthesis of their polymers.

Types of polymer

Homopolymer

Such a polymer is polymerised from the same (= *homos* in Greek) or only one kind of monomer. Some homopolymer fibres are: nylon 6, nylon 11, polyethylene, polypropylene, polyvinyl chloride, polyvinylidene chloride, polyacrylonitrile as distinct from acrylic and modacrylic. See also Tables 1.1 and 1.2.

Copolymer

Such a polymer is polymerised from two or more different monomers. There are four sub-categories of copolymers, as follows.

Alternating copolymer

Usually two monomers polymerise in an alternating sequence, as shown in Table 1.2. Some alternating copolymer fibres are: nylon 6.6 and polyester; see also Table 1.1.

Block copolymer

Two or more different monomers polymerise in blocks or segments before linking up to form the polymer; see Table 1.2. Block copolymers are still largely experimental.

Graft copolymer

The polymer is polymerised in such a manner that a segment, polymerised from the two or more different monomers used, attaches itself as a side-chain or forms a branch of the polymer; see Table 1.2. Sometimes the side-chain may be polymerised only from ... Then the other two monomers form the backbone of the ... In general, graft copolymer

Table 1.1 Chemical composition and structure of the most commonly used textile fibres.

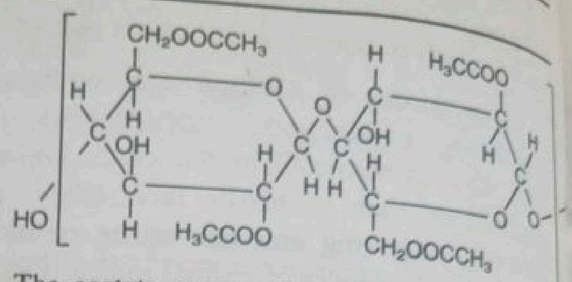
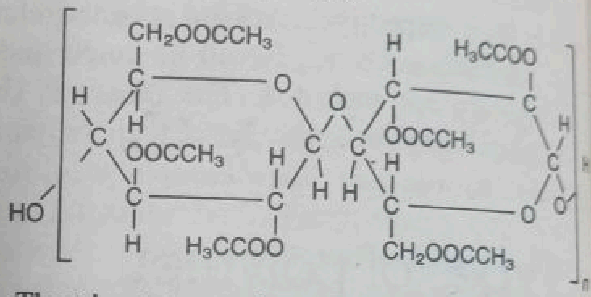
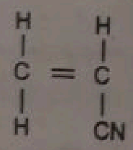
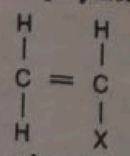
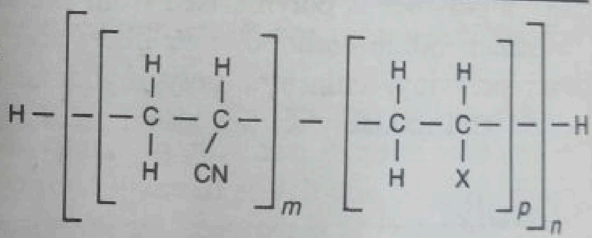
Fibre	Basic unit or monomer	Polymer
Acetate	The hydroxyl groups on the cellulose polymer are acetylated to the degree that the **acetate** or **secondary cellulose acetate polymer** has less than 92 per cent but at least 74 per cent of its hydroxyl groups acetylated; that is, 2.3 to 2.4 of the OH-groups per glucose unit are acetylated. This is usually shown as 4 acetate groups per cellobiose unit. The **triacetate** or **primary cellulose acetate polymer** has at least 92 per cent of its hydroxyl groups acetylated. In general, this is shown as 6 acetate groups per cellubiose unit.	 The **acetate** or **secondary cellulose acetate polymer**, which has a degree of polymerisation of about 130 units (i.e. $n = 130$).  The **triacetate** or **primary cellulose acetate polymer**, which has a degree of polymerisation of about 225 units (i.e. $n = 225$).
Acrylic	*Acrylic* At least 85 per cent of the mass of the acrylic fibre must be composed of **acrylonitrile monomers**; that is,  and no more than 15 per cent is complosed of the **copolymer;** that is,  where X is usually an anionic radical, e.g. —Cl, $—OOCCH_3$, $—CONH_2$, etc. *Modacrylic* At least 35 per cent but no more than 85 per cent of the mass of the modacrylic fibre polymer must be composed of **acrylonitrile monomers** ...	 **The acrylic polymer.** The values of *m* and *p* depend upon the mass of copolymer present; hence, whether it will be an acrylic or a modacrylic polymer fibre. The degree of polymerisation is about 2000 units (i.e. $n = 2000$).

Table 1.1 (continued)

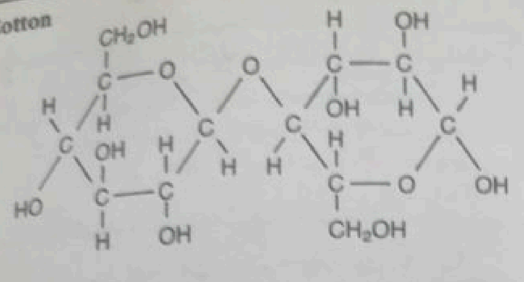
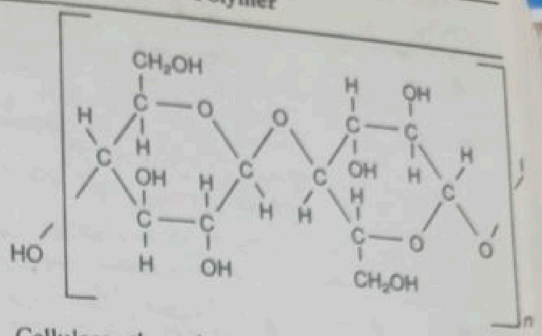
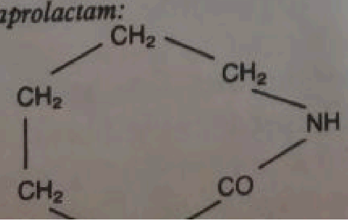
Fibre	Basic unit or monomer	Polymer
Cotton	 **Cellobiose**, the basic unit of cellulose.	 Cellulose, the polymer of cotton, with a degree of polymerisation of about 5000 cellobiose units (i.e. n = 5000).
Cuprammonium or cupro, polynosic or modal, and viscose	**Cellobiose** is the basic unit of the cuprammonium, polynosic and viscose polymer. See **cotton** for chemical formula details. *Note*: The name rayon is no longer preferred for these three fibres; see page 54.	Cellulose, in regenerated form, is the polymer of these three regenerated cellulose fibres; their degree of polymerisation is about: 250 cellobiose units (i.e. n = 250) for cuprammonium; 300 cellobiose units (i.e. n = 300) for polynosic; 175 cellobiose units (i.e. n = 175) for viscose.
Elastomeric	The complexity and length of the elastomeric monomers and the repeating units of their polymers makes it impossible to reproduce them satisfactorily within the confines of this table. Refer, therefore, to the section on elastomeric fibres in Chapter 5, 'The Synthetic Fibres' for the two types of elastomeric monomers and polymers; that is, the polyester and polyether types.	
Flax	Cellobiose — see **cotton** for chemical formula details.	Cellulose is also the polymer of flax, with a degree of polymerisation of 18 000 cellobiose units; that is, n = 18 000. See **cotton** for chemical formula details.
Nylon	For **nylon 6,6** the monomers are **adipic acid**: $HOOC(CH_2)_4COOH$ and **hexamethylene diamine**: $H_2N(CH_2)_6NH_2$. for **nylon 6** the monomer is *caprolactam:* 	$[-OC(CH_2)_4CONH(CH_2)_6NH-]_n$ Polyhexamethylene diamino adipate, the repeating unit of the **nylon 6,6 polymer**, with a degree of polymerisation of 50 to 80 units (i.e. n = 50 to 80) $[-(CH_2)_5CONH-]_n$ Polycaprolactam, the repeating unit of the **nylon 6 polymer**, with a degree of polymerisation of 200 units (i.e. n = 200).

Table 1.1 (continued)

Fibre	Basic unit or monomer	Polymer
Polyester	The monomers of the most common polyester are **ethylene glycol**, $HOCH_2CH_2OH$ and **terephthalic acid:** $HOOC-\langle O \rangle-COOH$	$[-OOC-\langle O \rangle-COO-(CH_2)_2-]_n$ Polyethylene terephthalate, the repeating unit of the **polyester polymer**, with a degree of polymerisation of 115 to 140 units (i.e. n = 115 to 140).
Rayon	*Note*: the name rayon is no longer preferred (see page 54).	
Silk and wool	The **silk fibroin polymer** is composed of 16 different amino acids, whilst the **wool keratin polymer** is composed of 20 different amino acids. **Amino acids** have this general formula: $H_2N-\underset{H}{\overset{R}{C}}-COOH$ where R = a radical, which is different for each of the 20 known amino acids.	$H-[-NH-\overset{R}{CH}-CO-NH-\overset{R'}{CH}-CO-NH-\overset{R''}{CH}-CO-]_n-OH$ The general formula for the **polypetide polymer.** Depending upon the type of radicals R, R′, R″, etc. the polypeptide polymer would be identified either as being a **silk fibroin polymer** or a **wool keratin polymer.** The degrees of polymerisation for silk and wool are not known.

fibres tend to have softening points which are too low for apparel and household textile use. However, Zefran, an acrylic graft copolymer fibre, has become successful. Its manufacturer describes Zefran as 'a graft copolymer of dye-receptive groups on a backbone of heat-resistant polyacrylonitrile'.

Random copolymer

The monomers are polymerised in no particular order or in a random fashion as shown in Table 1.2. Random copolymers tend to be polymerised mainly from only two different monomers. Some random copolymer fibres are acrylic and modacrylic; see also Table 1.1.

The term comonomer is also used. It refers to the monomer which is added to the polymerisation reaction to impart the special properties desired in the copolymer, e.g. greater affinity for dyes as in the case of acrylic and modacrylic fibres. For instance, the comonomer of acrylic and modacrylic polymers, which incidentally gave rise to the term copolymer, is the 'monomer other than acrylonitrile' as defined and described on pages 91 to 94.

Table 1.1 summarises the chemical composition and gives an indication of the structure for the polymers of the more commonly used textile fibres. Explanations of the chemical terms used can be found in the text and in the Glossary. Should further information be required, reference should be made to *The Penguin Dictionary of Science* by E.B. Uvarov et al., Penguin Books.

Intrapolymer bonding

Intrapolymer bonding means the bonds holding the atoms together to make up the fibre polymer. The fibre polymer is equivalent to a molecule — the smallest portion of a substance capable of existing independently and retaining the properties of the original substance.

Textile fibre polymers are organic compounds; the exceptions being the molecules comprising the man-made inorganic fibres and the natural mineral fibres. Describing

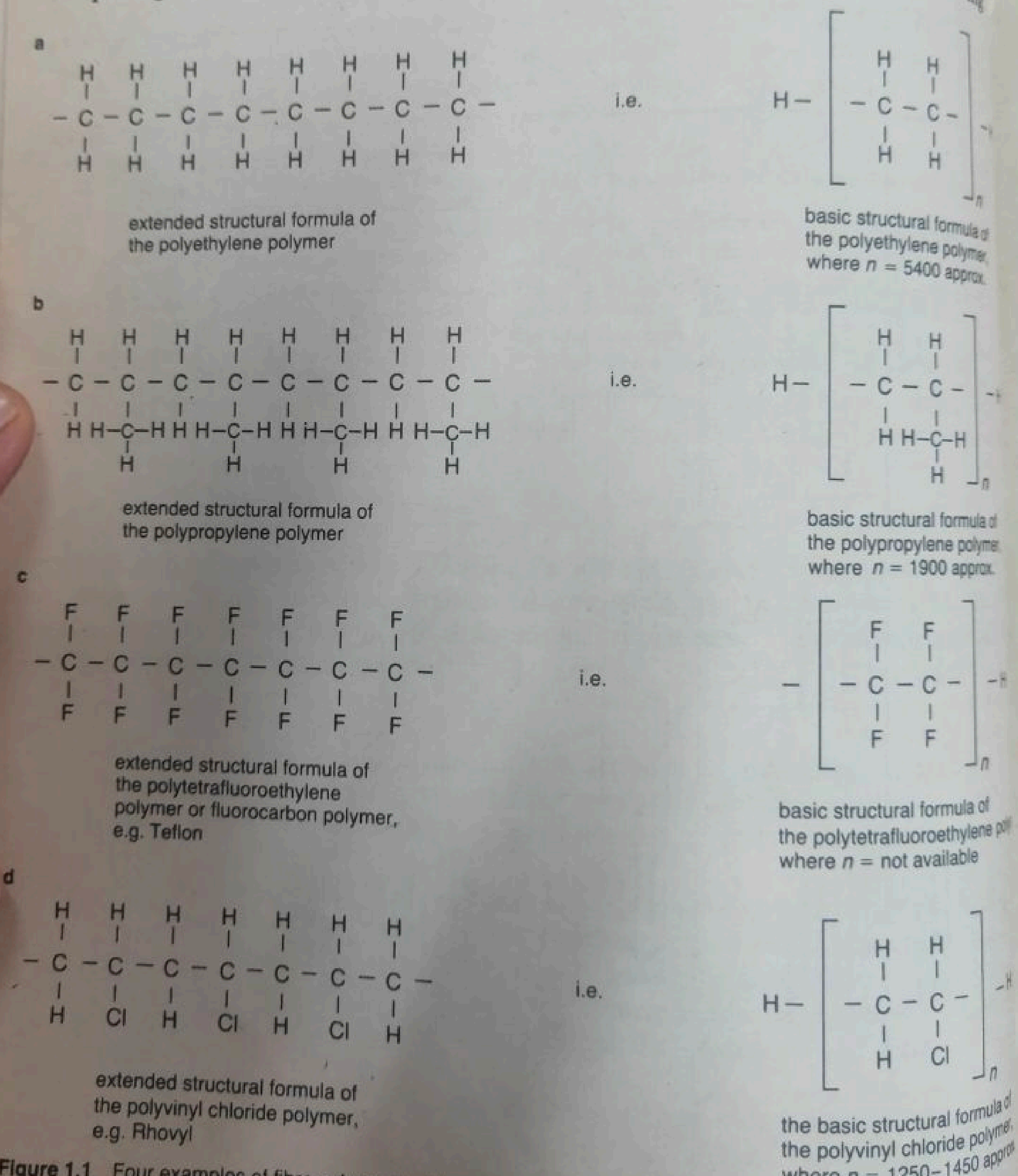
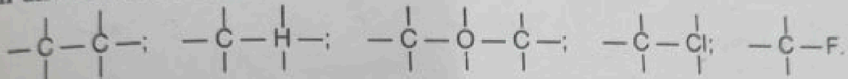


Figure 1.1 Four examples of fibre polymers to illustrate the fact that they are organic compounds predominantly composed of carbon and hydrogen atoms; other examples of fibre polymers are given in Tables 1.1 and 1.2.

fibre polymers as organic compounds signifies that they are predominantly composed of carbon and hydrogen atoms, with some oxygen, nitrogen, chlorine and/or fluorine atoms. This may be seen from the polymer formulae given in Tables 1.1 and 1.2 and Fig. 1.1.

The bonds between atoms in polymers

In general, single covalent bonds join the atoms forming the polymer. The single covalent bond is represented by a single short line drawn between the letters or symbols used to represent the atoms of each polymer; see Tables 1.1 and 1.2. Single covalent bonds, defined and explained on page 21, are chemically very stable and unreactive. In fact this type of bond is practically indestructible when it occurs between carbon and carbon atoms, carbon and hydrogen, carbon and oxygen, carbon and chlorine, and carbon and fluorine atoms:



It will be noticed (Tables 1.1 and 1.2) that much of the backbone of any fibre polymer consists of carbon segments of varying length, i.e. 
The reason for this is the ready formation of such segments which, owing to their single covalent bonding, contribute significantly to the chemical stability of the polymer and hence of the fibre.

The stability and unreactive nature of the single covalent bond joining the atoms of fibre polymers may also be expressed objectively. It has been estimated that the bond energy or bond strength is between 330 and 420 kilojoules for these single covalent bonds. This indicates a magnitude of bond strengths in excess of any other intra- or inter-polymer forces of attraction. It is for this reason also that it usually requires severe and prolonged exposure to chemicals and/or heat before fibre polymer breakdown occurs.

There are, of course, segments of the polymer backbone that are composed of other atoms, which influence the properties of the polymer as follows.

The amide or peptide group

This group is given in Fig. 1.2. When present in nylon polymers it is called the **amide group**; it is also present in silk, wool, mohair and all other animal or protein fibres, and is then called the **peptide group**. Figure 1.2 also shows the acid and alkaline hydrolysis of the amide or peptide group. This hydrolysis represents the most common chemical destructive attack upon the amide or peptide group during the life of the polymer, and hence of the fibre. Such hydrolysis (see Fig. 1.2) breaks the amide or peptide bonds, i.e. the single covalent bond between the carbon and nitrogen atoms. It is also important to note that the carbonyl oxygen of the amide or peptide group is strongly electronegative. This means it will develop a slight negative charge and give rise to hydrogen bonds. These hydrogen bonds will occur between the carbonyl oxygen and hydrogen atoms on closely aligned and adjacent polymers. An explanation of hydrogen bonds is given on page 16.

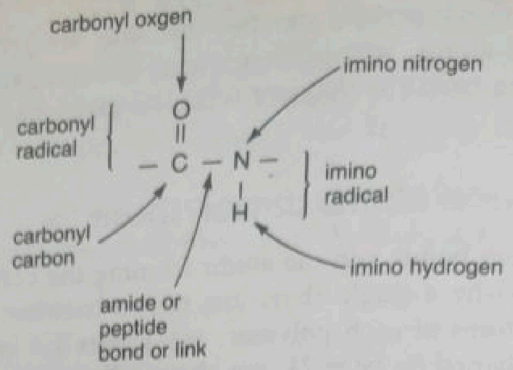


Figure 1.2a The amide or peptide group

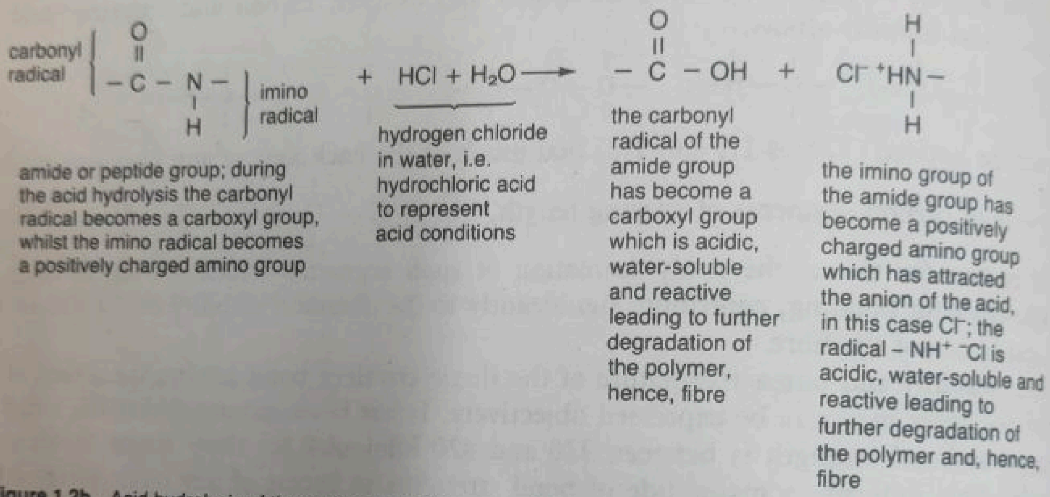


Figure 1.2b Acid hydrolysis of the amide or peptide group; the hydrolysis occurs at the single covalent bond which exists between the carbon and nitrogen atoms.

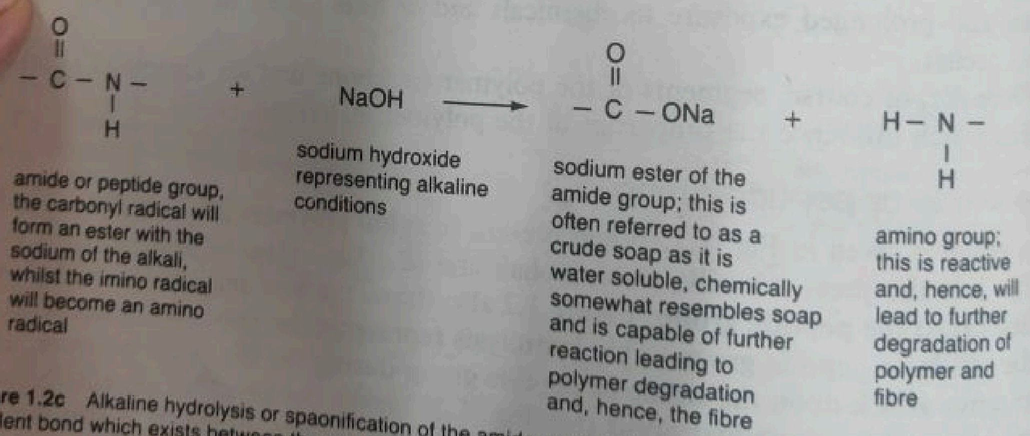


Figure 1.2c Alkaline hydrolysis or spaonification of the amide or peptide group; the hydrolysis occurs at the single covalent bond which exists between the carbon and nitrogen atoms.

The benzene ring

Benzene rings occur at regular intervals along the backbone of the common textile polyester polymer polyethylene terephthalate, e.g. Dacron, Terylene, Tetoron, Tre-

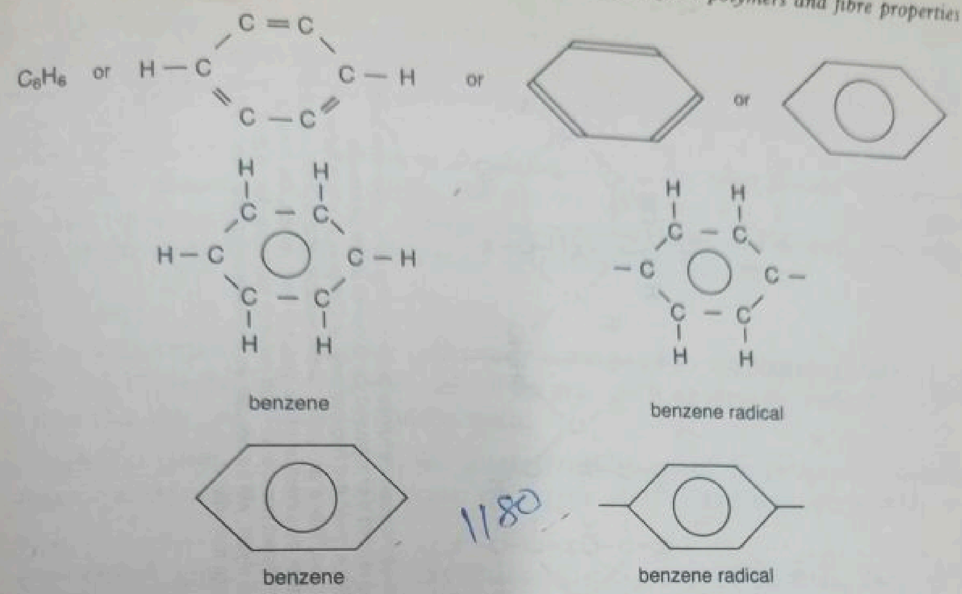


Figure 1.3 Benzene, its molecular and structural formula and symbolic representation. See text below for explanation

vira, etc. Invariably the benzene ring is a constituent of dye molecules (see Chapter 6, Figs 6.1 and 6.15 for example). The benzene ring is sometimes referred to as the **aromatic radical**. This term came about from the pleasant and/or distinctive odours of many naturally occurring substances, such as balsams, resins and by-products from coal tar, which once were the main source of benzene.

The benzene molecule is a hexagon, often referred to as a **ring structure**, composed of carbon and hydrogen atoms as shown in Fig. 1.3. The accepted symbol for benzene in chemical formulae is a hexagon containing a circle; the circle indicates the resonance or orbiting electrons of the benzene molecular structure. It is the unique manner in which the carbon atoms of the benzene molecule adhere to their electrons which makes the benzene molecular structure relatively unreactive. Thus the presence of benzene in fibre polymers and dye molecules may be taken as an indication of chemical stability and resistance to degradation. Of course, this may not have been the primary intention when the fibre polymer or dye molecule was synthesised. Rather, it may have been more the ability of the benzene-containing compound to react in a certain way (i.e. to provide a particular hue, etc.) which prompted its initial use. Its contribution to greater stability of the resultant fibre polymer or dye molecule is of distinct advantage.

Ether linkage

The ether linkage may be found in such polymers as cellulose, elastomeric, ester-cellulose and polyesters. It exists between carbon and oxygen atoms thus:

$$-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{O}}-\overset{|}{\underset{|}{C}}-.$$

The linkage obtains its name from the family of organic compounds in which it is found, namely the ethers — diethyl ether being the well known anaesthetic ether.

Ethers are chemically quite unreactive. One reason for this is the great chemical stability of the carbon–oxygen linkage found in every ether molecule. In general, an ether linkage in a fibre polymer tends to be the most durable and least affected by degrading agents.

There is, however, one exception to the above. This is the ether linkage in cellulose known as the **glucoside link**. It links the glucose units (see Fig. 2.4). Under acidic conditions the glucoside link will undergo hydrolysis as shown in Fig. 1.4. This is the reason for the destructive effect with acids have upon cellulosic fibres.

Ester group

Esters may be regarded as organic salts: they correspond to the inorganic salts. They are formed by replacing the hydrogen of an acid with an organic radical. In fibre polymers this is usually the reaction between:

a **a carboxyl group**, i.e. –COOH, the characteristic group of the commonly occurring organic acids called carboxylic acids; e.g. acetic acid, formic acid, citric acid, etc.
and

b **a hydroxyl group**, i.e. –OH, the characteristic group of alcohols, such as the monohydric alcohols (e.g. ethanol) as found in alcoholic drinks, which only have one –OH group per molecule; and the polyhydric alcohols such as cellulose (see Table 1.2 and Fig. 1.5) which have more than one –OH group per molecule.

Figure 1.5 shows the formula of the ester group. The group is not resistant to alkalis — it is subject to saponification or alkaline hydrolysis, as shown in Fig. 1.5b. The saponification of the ester group produces water-soluble and reactive end-groups, leading to further degradation of the polymer and hence of the fibre.

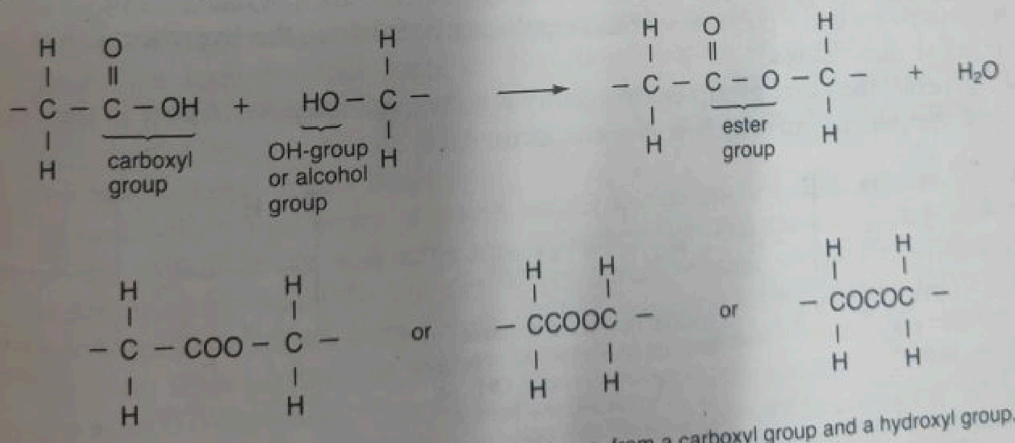


Figure 1.5a Formation of an ester group, generally as shown, from a carboxyl group and a hydroxyl group, –OH group, or alcohol group. The ester group is often also shown as depicted below.

Hydroxyl group or –OH group

By definition, the hydroxyl group is the univalent –OH group, pronounced O-H-group. It is attached by a single covalent bond as a side-group to fibre polymers (e.g. cellulose polymers; see Figs 1.4 and 2.4). This distinguishes it from the *free* hydroxyl

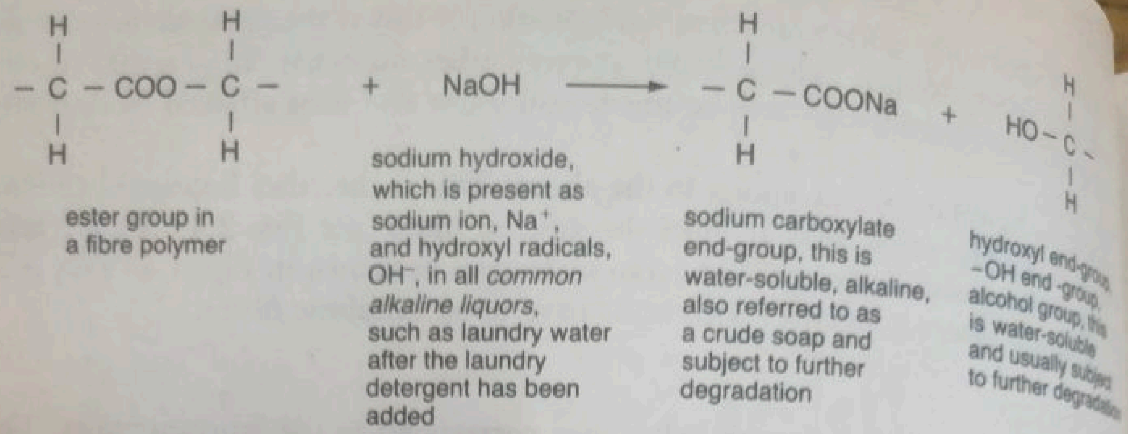


Figure 1.5b Alkaline hydrolysis or saponification of an ester group in a fibre polymer. *Note*: saponification means soap-making and the sodium carboxylate group is the typical water-soluble end-group of all soaps made from natural oils or fats with sodium hydroxide.

group which is the cation, ion or negative radical OH^-.

The presence of –OH groups on fibre polymers is of two-fold significance:

a The –OH groups are polar and will therefore attract water molecules, which are also polar. Thus –OH groups are mainly responsible for the moisture absorbency of a fibre, and hence its comfort when worn.

b The polarity of –OH groups will give rise to the formation of hydrogen bonds (see page 16 for explanation). The formation of such hydrogen bonds will contribute significantly towards the coherence of the fibre's polymer system.

The presence of –OH groups on fibre polymers should not be underestimated. The importance is illustrated by the fact that constant efforts are being made to have –OH groups introduced onto the hydrophobic, synthetic fibre polymers. The presence of –OH groups on these polymers would significantly enhance the hygroscopic nature and comfort of these fibres.

In general, the –OH group is chemically reactive and may contribute to the degradation of the polymer of which it is a constituent.

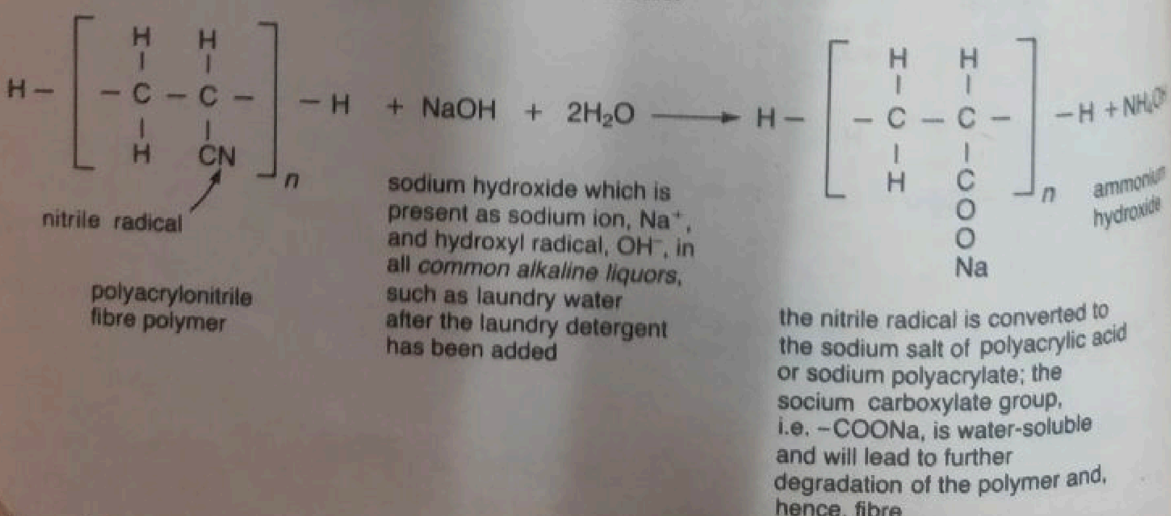


Figure 1.6 Alkaline hydrolysis or saponification of the polyacrylonitrile fibre polymer; ... indicates how

Nitrile group

This is the characteristic polymer side-group of acrylic and modacrylic fibres, i.e. –CN (see also Tables 1.1 and 1.2). In general, the nitrile group does not react with acids or break down in acidic conditions. It is, however, subject to alkaline hydrolysis or saponification, as would occur during normal laundering. Under normal circumstances this is not very noticeable, because the crytallinity or good orientation of the polymer system of the acrylic fibre allows such hydrolysis to occur only on the surface of the fibre.

Inter-polymer forces of attraction

It is stated on pages 1, 8 that textile fibres are composed of polymers; polymers being the equivalent of molecules of other substances. This statement of fact requires the development of some sort of abstract or real picture of a coherent mass of polymers forming the fibre, which may be called the polymer system of the fibre.

The coherence of the polymer system of a fibre is due to the four inter-polymer forces of attraction: **van der Waals' forces, hydrogen bonds, salt linkages**, and **cross-links** (see Table 1.3 for a detailed summary of these forces).

A more detailed description of the four inter-polymer forces follows.

Van der Waals' forces

These are very weak inter-polymer forces of attraction, named after the Dutch physicist Johannes Diederik van der Waals who first postulated their existence.

Van der Waals' forces may be defined as very weak electrostatic forces which attrac neutral molecules to each other in gases, liquefied and solidified gases, organic liquids, and, most importantly in this context, **organic solids such as textile fibres**. They become an inter-polymer force of attraction as a result of electrons of very closely adjacent atoms *moving in sympathy with one another*. A more detailed explanation of th formation of van der Waals' forces requires the use of quantum mechanics, which i beyond the scope of this book.

Provided any two or more atoms and/or molecules are close enough together, the van der Waals' forces will come into existence between them. Fibre polymers need t be about 0.2 nm apart for van der Waals' forces to occur along their length. Such ver close alignment of polymers occurs in the crystalline regions of the polymer system o any fibre. Thus, it may be assumed that van der Waals' forces exist between the po lymers of the crystalline regions of any fibre'e polymer system.

It is important to remember that the diameter or size of the atoms which give rise t van der Waals' forces influences the relative strength of this very weak inter-polyme force of attraction. This means that larger atoms give rise to stronger van der Waals forces than smaller atoms. For instance, the hydrogen atom is the smallest, being abou 0.06 nm in diameter. By comparison, the chlorine atom is about 0.2 nm, i.e. mor than three times as large in diameter. Consider now the polymer system c ...vinylidene chloride fibres. The polymer systems of both fibre ... forces. However, because of the presence c

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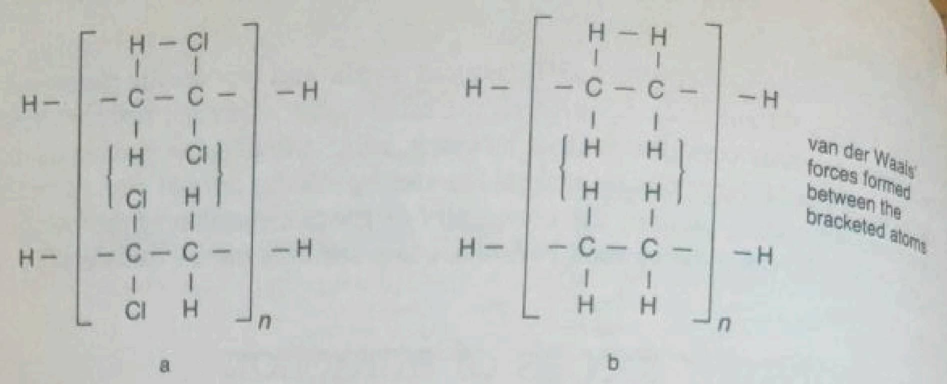


Figure 1.7
a Two adjacent or very closely aligned polyvinylidene chloride polymers; owing to the presence of the chlorine atoms, stronger van der Waals' forces will be formed.
b Two adjacent or very closely aligned polyethylene polymers; owing to the presence of only hydrogen atoms, weaker van der Waals' forces will be formed.

chlorine atoms on the polyvinylidene chloride polymers, the van der Waals' forces formed in the polymer system of this fibre will be stronger than those formed in polyethylene (see also Fig. 1.7).

Van der Waals' forces become of utmost importance when none of the other forces of inter-polymer forces of attraction is present to a significant degree. This is the case with such fibres as acrylic, polyester, polyethylene, polypropylene, and the chlorofibres. Their polymer systems need to be made highly crystalline. Only then will sufficient van der Waals' forces occur along the lengths of their polymers to make them useful fibres.

The influence of the difference in strength of the van der Waals' forces in the above two fibres is illustrated by their melting points. In general, the stronger the inter-polymer forces of attraction, the higher the melting point of the polymer system and, hence, of the fibre:

Fibre	Melting point range
polyethylene	110–140°C
polyvinyl chloride	170–200°C

Van der Waals' forces are also formed between fibre polymers and dye molecules, when these come close enough together. In this way, van der Waals' forces contribute towards the colour-fastness of dyed or printed textile fibres.

Hydrogen bonds

These may be written as H-bonds. Hydrogen bonds are weak electrostatic bonds which occur between covalently bonded hydrogen atoms and the strongly electronegative atoms: oxygen, nitrogen, fluorine and chlorine. The formation of a hydrogen bond requires that:

a the hydrogen atom assumes a very slight positive charge or polarity, shown as δ^+ in Fig. 1.8, and pronounced delta positive;

oxygen, nitrogen, fluorine or chlorine atoms, i.e. the strongly electronegative atoms, assume a very slight negative charge or polarity, shown as δ^- in Fig. 1.8 and pronounced delta negative;

and

c the distance is less than about 0.5 nm between the two very slightly polar, but oppositely charged atoms of **a** and **b** above.

The most common hydrogen bond in the polymer system of textile fibres is that formed between hydrogen and oxygen atoms. This means that the hydrogen bond may be formed between:

the –OH groups on closely adjacent cellulose polymers;

the amide groups of nylon polymers; and

the peptide groups of the polymers of the protein fibres (see also Fig. 1.8).

It is now considered doubtful that significant hydrogen bonding occurs between the nitrile nitrogen of acrylic polymers and hydrogen atoms on adjacent polymers (see also Table 1.2). It is necessary to point out that hydrogen bonds formed between hydrogen and nitrogen atoms are weaker than those formed between hydrogen and oxygen atoms, because nitrogen becomes less electronegative than oxygen.

Before a hydrogen bond can form, the two participating atoms, say hydrogen and oxygen, must develop or assume very slight, but opposite, charges or polarity. The development of this polarity may be explained by considering the hydrogen bond which can come into existence between the **imino hydrogen** of an amide or peptide group on one polymer, and the **carbonyl oxygen** on an amide or peptide group on a

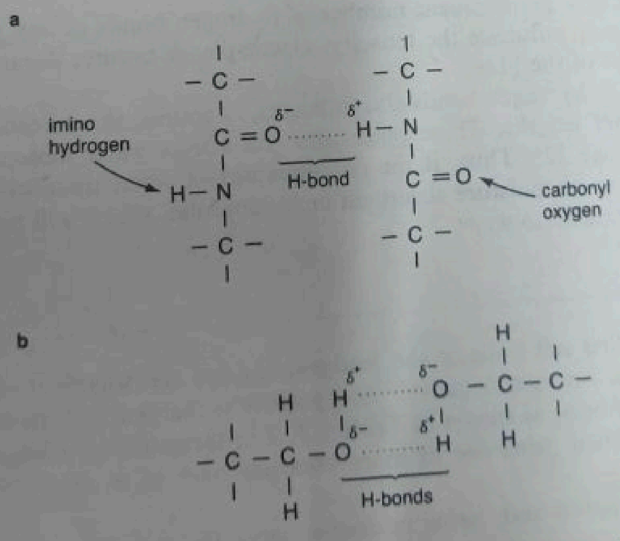


Figure 1.8
a The existence of a hydrogen bond between the carbonyl oxygen and imino hydrogen of two very closely adjacent amide or peptide groups. Note how the very slight polarity or partial charge, as it is sometimes called, is shown against the relevant atoms.
b The existence of a hydrogen bond between two hydroxyl groups on very closely adjacent cellulose polymers. Note that two hydrogen bonds are formed between any two –OH groups.

very closely adjacent polymer (see also Fig. 1.8). The nitrogen atom, to which the imino hydrogen atom is bonded, is a strongly electronegative atom. This means that the nitrogen atom will disproportionately concentrate its own electrons and the one electron of the hydrogen atom about itself. This tends to give the nitrogen atom an excess of electrons and thus cause it to assume a very slight negative polarity. This is shown as δ^- in Fig. 1.8. The lopsided concentration of electrons towards the nitrogen atoms leaves the hydrogen atom with a deficiency of electrons. This will cause it to assume a very slight positive polarity, shown as δ^+ in Fig. 1.8. In the carbonyl group of the amide or peptide group a similar electron displacement occurs. The oxygen, which is linked by a double covalent bond to the carbonyl carbon atom, is also a very strongly electronegative atom. It will therefore tend to concentrate its own electrons and those of the carbon atom about itself. This gives a disproportionate concentration of electrons about the oxygen atom, causing it to assume a very slightly negative polarity. The carbonyl carbon atom will, of course, assume a very slightly positive polarity. These polarities are shown as δ^- and δ^+ respectively in Fig. 1.8. Thus, as the carbonyl oxygen and the imino hydrogen assume opposite polarities, a force of attraction known as the hydrogen bond will form between them.

With regard to the hydrogen bond formed between two –OH groups on adjacent cellulose polymers, the oxygen atom will assume a very slight negative polarity as explained above. This causes the hydrogen atom of the –OH group to assume a very slight positive polarity, resulting in the formation of a hydrogen bond as shown in Fig. 1.8.

It is also possible for hydrogen bonds to form within the one polymer as depicted in Chapter 4, Fig. 4.7b.

The presence of a predominant number of hydrogen bonds in any polymer system will advantageously influence the tenacity, elastic-plastic nature, durability, and heat-setting properties of the fibre.

The presence of hydrogen bonds also indicates, of course, the existence of polar sites along the polymer lengths. These polar sites will attract water molecules, which are also polar (see page 22). Thus, if the polymers attract water molecules, the polymer system will tend to be moisture absorbent or hydrophilic, which will tend to make the fibre more comfortable to wear.

Salt linkages

These are also called **salt links** or **salt bridges**, and are **electrovalent** or **ionic bonds**. Salt linkages occur between negatively and positively charged radicals on very closely adjacent fibre polymers, as shown in Table 1.3. The formation of a negatively charged radical occurs when it gains one or more electrons over its normal electron complement.

Electrons are negative and, being in excess, cause the radical to become negatively charged. This negative charge is shown on the radi... number of negative signs shown ... radical has ...

Table 1.3

Inter-polymer force of attraction and its formation	Bond energy or bond strength in kilojoules*	Relative strength	Occurs between the polymers of	Relative importance
van der Waals' forces formed between atoms along the length of adjacent polymers when these are less than 0.3 nm apart but no closer than about 0.2 nm	8.4	very weak	all fibres	they are the only int polymer force of attracti existing in the polymer s tem of polyethylene, poly ropylene, polyvinylchlori polyvinylidene chlori primary cellulose acetate a 100 per cent polyacrylonitr fibres; they are considered to be t predominant inter-polym force of attraction in the p lymer system of acrylic, mc acrylic and polyester fibres
hydrogen bonds formed between hydrogen and oxygen atoms, and, hydrogen and nitrogen atoms on adjacent polymers when these are less than 0.5 nm apart; note, the hydrogen–oxygen bond is stronger than the hydrogen–nitrogen bond	20.9	weak	natural, regenerated cellulose, nylon, polyvinyl alcohol, polyester, protein and secondary cellulose acetate fibres	they are mainly reponsi for the tenacity and the el tic-plastic nature of the na ral, regenerated cellulo nylon, polyvinyl alcohol a protein fibres; they con bute significantly towards t heat setting property of ny and protein fibres; hydrogen bonds occurring the polymer system of poly ter fibres are very weak a not consider to be importa insignificant hydrogen bo are formed in the polym system of secondary cellul fibres; there is doubt abo hydrogen bond formation the polymer system of ac lic and modacrylic fibres
salt linkages formed between the carboxyl radical on one polymer and the positively charged or protonated amino group on an adjacent polymer, i.e. $-C-O^{-}\ {}^{+}H_3N-$ (less than 0.1 nm)	54.4	strong	protein and nylon fibres	they contribute towards t tenacity of the fibre; attr water molecules, hence, e hance the hygroscopic natu of the fibre; attract the ani of acid dyes, i.e. they a very good dye sites; m make the fibre's polymer sy tem liable to chemical d gradation.

Chapter 13

COTTON

a natural cellulose fiber

Cotton is a fiber that grows from the surface of seeds in the pods, or bolls, of a bushy mallow plant. It is composed basically of a substance called *cellulose*.

HISTORY OF COTTON

Cotton has been cultivated for more than 5000 years. Archeological finds indicate cotton was grown and used for textile purposes in the Indus Valley well before 2100 B.C., in Mexico by 3500 B.C., in Peru by 2500 B.C., and in the southwestern United States by 500 B.C. Fragments of fiber and bolls dating from 5800 B.C. were found in Mexico, although there is a question as to whether cotton was used as a textile that early. Cotton was used extensively in the Medo-Persian Empire and may have been used in ancient Egypt as well. It was introduced into the Mediterranean countries by the Arabs and into other parts of Europe by the Crusaders. The use of cotton in England is mentioned in writings of the thirteenth century, although its use did not become general until the first half of the sixteenth century. In the United States, cotton was cultivated by the colonists in the early seventeenth century. The impetus of the industrial revolution, represented in the cotton industry by the invention of the carding machine and the spinning mule in England and by the invention of the cotton gin in the United States, resulted in vastly increased cotton production and manufacturing. Today cotton fields extend across the southern United States from North Carolina to California.

Cotton fabrics have been so well known and so extensively used throughout the world for hundreds of years that the spinning of the cotton fiber into yarn, the wearing of cotton fabric, and many of the finishing processes used for cotton goods come first to mind and naturally serve as foremost examples in a study of fiber and fabric. Cotton has been of service to mankind for so long that its versatility is almost unlimited and new uses are constantly being discovered. It can be depended on to serve many purposes. Not only is cotton a textile in its own right, but some of its byproducts form the base for some of the manmade textile fibers.

KINDS AND TYPES OF COTTON

Different kinds and types of cotton are grown in various parts of the world. Some of their basic characteristics differ. Variations among cotton fibers also occur because of growth conditions including such factors as soil, climate, fertilizers, and pests. The quality of cotton fiber is based on its color (degree of whiteness), length (or staple), fineness, and strength. Usually, the longer fibers are finer and stronger.

The particular kind of cotton is often identified by the name of the country or geographical area where it is produced, and although a major portion of the world's cotton is Upland type, it is still known by the place of production whether Brazil, Zaire, Greece, Pakistan, Russia, Syria, Turkey, Uganda, or San Joaquin Valley. The quality is associated with the name. The better known kinds and types of cotton used in the United States are Upland, American pima, Egyptian, and Asiatic cotton.

Upland Cotton

American Upland cotton constitutes over 99 percent of the United States cotton crop and is used for many fabrics either wholly or as a component of blends with manmade fibers. The particular kind of Upland cotton from which these fabrics are made is important because the quality and characteristics vary among the kinds.

Generally speaking, Upland cotton fibers are fairly white, strong, and dull, and range in staple length from ⅞ to 1¼ inches (22–32 mm). The Upland cottons are usually categorized as short-, medium-, and long-staple. The short-staple cottons are less than 1 inch (25 mm) and are produced in Oklahoma and central and west Texas. Lankart, GSA, Paymaster, and Tamcot are the principal varieties. The medium-staple cottons are 1 1/32 to 1 3/32 inches (26–28 mm) in length and are produced in the Southeast, the Mississippi Valley, and the low valleys of Arizona and California. The principal varieties are Deltapine and Stoneville. The long-staple cottons are 1⅛ inches (29 mm) or longer and are grown in the high-altitude areas of the Southwest. Acala is the primary variety. The cotton grown in the San Joaquin Valley of California has a staple length from 1 3/32 to 1 5/32 inches (28–29 mm). The fiber is stronger than the other Upland kinds.

American Pima

American Pima cotton is grown in the upper Rio Grande Valley of Texas, in New Mexico, Arizona, and southern California. The varieties Pima S-3 and Pima S-4, account for most of the acreage. The staple length is from 1⅜ to 1½ inches (35–38 mm) and the fiber is fine, strong, lustrous, silky, and creamy-brown-white in color. American Pima fiber is used primarily for sewing thread although a small amount is used in high-quality broadcloth and other fabrics where silky smoothness, softness, and luster are desired.

Egyptian

Egyptian cotton is imported into the United States in small quantities. Menoufi and Giza 68 are the varieties used to produce most of the exported crop. The fibers are light brown, fine, strong, and 1¼ to 1½ inches (32–38 mm) in length. They are used in the same applications as American Pima.

Giza 45 is exported in limited quantities. The fiber is light brown, fine, strong, and 1⅜ to 1⅝ inches (35–41 mm) in length. It is used in applications where fine yarns or strong yarns are required.

Asiatic

Asiatic cottons are produced in India, China, and the Near East. For the most part these are coarse fibers less than 1 inch (25 mm) in length. The major usage in the United States is in surgical supplies.

FROM FIELD TO MILL

Cultivating Cotton

Cotton can be cultivated only in warm places, which is the reason for its cultivation in the southern part of the United States. Cotton requires about two hundred days of continuous warm weather with adequate moisture and sunlight; frost is harmful to the plant. The ground must be thoroughly plowed, and the soil pulverized. In the United States, usually in March or April, carefully selected cottonseeds are planted in rows. Approximately thirty-five days pass before the seeds develop. The plants require careful fertilization.

The cotton plants must be protected from being crowded out by weeds. A variety of techniques is employed depending upon such factors as topography, soil texture, frequency of cultivation, and necessity of irrigation. The plants are generally thinned out and weeded when they are from 5 to 7 inches (15–20 cm) tall. This may be done by hand or by mechanical rotary hoes. Flame cultivators, which throw out small flames from jets set low to the ground between the rows of young cotton plants, are sometimes used to burn the thin-stemmed weeds and grass and leave the stronger, woody cotton plants unharmed. Some farmers use geese as cultivators since the geese voraciously eat the young weeds and grass but do not bother the cotton plants. Chemicals specifically developed to kill certain weed and grass seeds are often spread or sprayed on the ground at the time the cotton is planted. Other chemicals are sprayed on weeds after they emerge, but care must be taken to avoid contact with the cotton plants as they could be damaged.

Buds appear a few weeks after the plant emerges. They begin to bloom as creamy white blossoms about 3 weeks later in June or July. These blossoms change to pink and then to reddish purple. Within three days their petals fall off, leaving the ripening seedpod. The fibers that grow from the surface of the seeds cause the pod to expand to about an inch (25 mm) in diameter and 1½ inches (40 mm) in length to form the cotton boll. During this period, the plant is subject to attack by many insects (in particular, the boll weevil that lays its eggs inside the buds), which, when they are hatched, feed inside the maturing boll. To protect the plants, insecticides are sprayed by hand, tractors, or airplanes.

The cotton bolls grow to full size by August or September, a month and a half to two months after the blossoms first appeared. When fully grown, the cotton plant may be from 3 to 6 feet (1–2 m) in height. Its wide green leaves conceal some of the bolls, which begin to burst with fleecy white cotton fiber. This indicates that the cotton bolls are ready for harvesting (see Figure 13-1*a* and *b*).

Figure 13-1 (*a*) Cotton plants ready for harvesting. (*b*) Close-up of a closed cotton boll and an open boll.

Harvesting

By the time the bolls have all opened, some leaves will have fallen off. To remove all of the leaves, the plants are defoliated by spraying them with a chemical, causing the remaining leaves to wither and fall. The full, ripe bolls are then picked by machine, one or two rows at a time (see Figure 13-2).

Ginning and Baling

When the raw cotton is harvested, it contains seeds, leaf fragments, dirt, and other material that must be removed before the fiber can be baled. Cottonseeds alone constitute approximately two-thirds of the weight of the raw cotton when first picked. The seeds are removed by the cotton gin. (The cotton gin was invented by Eli Whitney in 1794. Whitney's invention was not immediately accepted, and he suffered serious financial loss. It was subsequently promoted by others, and it became a major impetus in the growth of the cotton industry. The invention of the cotton gin also led to the dominance of the southern United States as a cotton producer.)

Essentially, the cotton gin has rows of revolving saw-toothed bands that pull the

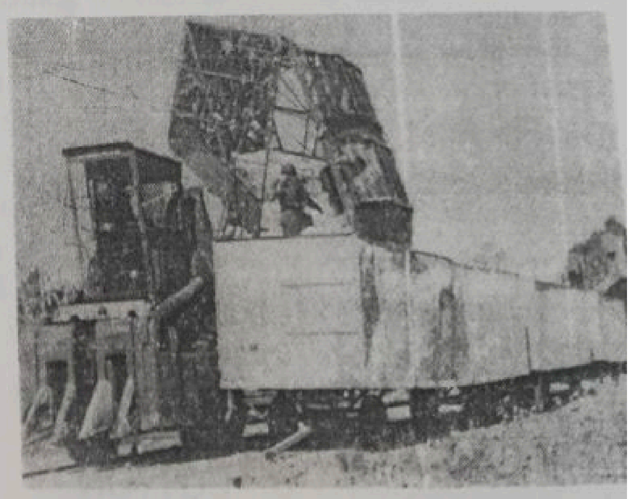


Figure 13-2 Cotton-picking machine being un loaded. Note the two scoops in the front throug which rows of cotton are picked.

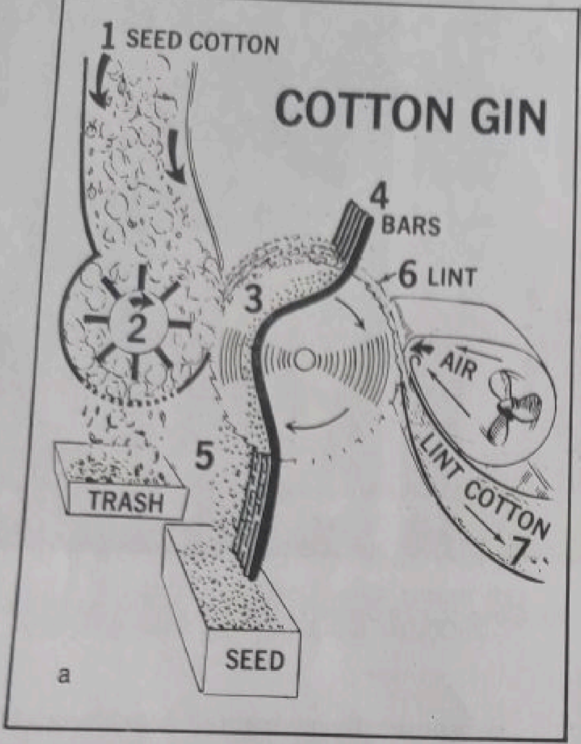


Figure 13-3 (*a*) Shown in the drawing are the following basic principles of the cotton gin: (1) Seed cotton enters gin. (2) Roll throws seed cotton against bars. (3) Saw teeth take cotton up and against bars. (4) Bars near saws on both sides let lint pass through but hold back seed. (5) Seed falls into conveyor. (6) Lint on sawtooth is struck by blast of air, and (7) blown into lint cotton conveyor pipe. (*Courtesy Bibb Manufacturing Co.*) (*b*) Cotton fiber, which has entered the cotton gin from a pneumatic conveyor, is here seen falling on covered gin saws after sand and coarse soil have been removed. The saws separate the seeds from the fiber; the fiber is removed from the sawtooth by a blast of air and is whisked toward the back. The seeds then fall into a conveyor at the bottom of the machine. (*Courtesy National Cotton Council of America*)

fiber away from the seeds as well as remove other extraneous material (Figure 13-3). The cottonseeds are one of the valued byproducts. The cotton fiber is compressed into rectangular bales, which are covered with jute or polypropylene bagging and bound with iron bands. These bales weigh about 500 pounds (225 kg) each.

BYPRODUCTS OF COTTON

The raw cotton passes through several cleaning processes before it is baled as well as after it is unbaled at the cotton mill. As a result, the grower obtains valuable byproducts that amount approximately to one-sixth of the entire income derived from the cotton plant. Cotton is therefore important because of its contributions to other industries as well as to the textile industry.

Cotton Linters

Linters are the short, fuzzy hairlike fibers that remain on the seeds after they have been separated from the fiber in the cotton gin. The cotton linters are removed by a second ginning process. They are used in the manufacture of rayons and acetates, plastics, shatterproof glass, guncotton, photographic film, and fast-drying lacquers, and for other purposes.

Hulls

The hulls, which are the outside portion of the cottonseeds, are obtained after the linters have been removed. The hulls are rich in nitrogen, an important plant food, and are used as fertilizer, in the manufacture of paper, plastics, and cattle feed, and as a base for explosives.

Inner Seeds

The meat of the seed inside the hull yields *cottonseed oil*, which is used in cooking oils and compounds and in the manufacture of soap. The residue of the inner seed becomes cattle feed.

PROCESSING, BLENDING, AND MIXING COTTON

As observed in Chapter 2, cotton fiber may be spun alone or blended with other fibers in making yarns. Cotton yarns are also combined or mixed with other yarns in making fabrics. These techniques contribute to fabrics such desirable cotton properties as softness, strength, absorbency, and affinity for color.

FINISHING COTTON FABRICS

The finishing processes given to cotton were reviewed in Chapters 9 and 10. They may be summarized as follows:

Ammoniating—for strength, abrasion resistance, luster, and affinity for dyes

Antibacterial finish—for hygienic protection

Beetling—for flattened effects

Bleaching (full)—for clear whiteness

Calendering—for luster

Compressive shrinkage—for maximum preshrinking

Crepe effects—for wrinkle resistance and textured surface

Drip-dry—for no ironing

Embossing—for decoration

Flame retarding—for fire inhibition

Glazing—for luster

Insulating—for warmth

Mercerizing—for strength, luster, and affinity for dyes

Moiréing—for variable luster and variable pattern

Napping—for softness, warmth, and increased absorbency

Permanent pressing—for easy care

Preshrinking—for serviceability

Schreinerizing—for luster

Singeing—for smoothness

Slack mercerizing—for stretch

Stain repelling—for easy care

Stiffening—for smoothness and body

Water repellency—for resistance to water and rain

Weighting—for bulk

Wrinkle resistance—for retention of appearance

The types of dyes used for cotton and their degree of fastness to light and to washing were explained in Chapter 11.

Simulating Linen

Cotton yarn can be spun to simulate the irregularities characteristic of linen fiber. The fabric is woven in the damask and other patterns usually associated with linen fabrics and is then sized, beetled, and calendered similarly to linen.

Simulating Wool

Cotton fibers can be treated with chemicals to give them the roughness characteristic of wool fibers. The fibers are spun into thick yarns to increase the similarity. The finished fabric is napped or roughened to produce a wool-like surface. Because Peruvian cotton fiber has crimp, an inherent similarity to wool fiber, it is sometimes mixed with American Upland cotton to simulate wool.

Simulating Silk

The highest quality of cotton fiber, when spun to a high yarn count and then mercerized, simulates silk. The use of the satin construction in weaving produces a silklike luster. The cotton fabric may be singed and calendered to smooth its surface and to increase the luster. Cotton fabrics are frequently Schreinerized to obtain an added lustrous effect.

EVALUATING COTTON FABRICS

Manufacturers put labels on finished consumer's goods to give such vital information as the thread count, fiber content, expected shrinkage, permanency of crispness (if any), fastness of dye to strong light, washing, dry cleaning, and general instructions on the maintenance and care of the fabric. Such labels are designed to protect and help the consumer. If one understands them, one can estimate how long the fabric or garment that one is purchasing may be expected to give good wear. These labels also protect the manufacturer from the consumer's possible misunderstanding of the quality and durability of a fabric and from complaint if it is improperly handled when washed or drycleaned.

The information gained in previous chapters of this book concerning the essential qualities of the fibers and their spinning into yarn and construction into fabric can now be applied to the purchase of consumers' goods.

Strength. Strength of a fiber is indicated by the ability to resist being pulled or torn apart when subjected to stress or tension. Cotton fiber is relatively strong due to the intrinsic structure of layers of crisscrossed, minute, spiraled fibrils that compose the fiber cell (see Figure 13-4). Strength is also determined by the character of the cotton yarns, which should be of

Figure 13-4 Diagram of inner layer of an enlarged cotton fiber shows how fibrils crisscross and double back. This structure contributes greatly to the strength of cotton. (*Courtesy* CIBA Review)

long staple and tightly twisted. Compact construction, represented by high thread count, helps a fabric keep its shape and give longer wear. A sample of the fabric may be tested for strength by holding it in both hands and pressing down firmly with the thumbs while pulling. If the cloth gives easily, it will not stand the strain of wear. Strength can be substantially improved by mercerizing or ammoniating.

Elasticity. Elasticity refers to the extent to which a fiber can be elongated by stretching and then returning to its former condition of size or length. Cotton fiber has very little natural elasticity. This characteristic can be altered to varying extents by hard-twisting fibers into creped yarns and by using fabric construction techniques such as knitting. The slack mercerization technique may be used to give cotton fabrics some stretch in the warp and/or filling, thereby reducing the binding characteristic of the cotton fabrics.

Resilience. Resilience refers to the extent to which a fabric can be deformed by compression or crushing and return to its original condition. The tendency of cotton fabrics to wrinkle easily may be offset by finishing processes that give a wrinkle-resistant quality.

Drapability. The ability of a fabric to hang easily and fall into graceful shape and folds indicates its drapability. The characteristic is dependent upon the kind of fiber, yarn, and construction of the fabric as well as finish given to it. Cotton does not intrinsically have the body and suppleness required for good drapability. However, the nature and compactness of the fabric construction can improve it. This can be enhanced further by sizing and other finishes.

Heat Conductivity. The extent to which heat can be conveyed through a fiber or a fabric indicates its heat conductivity. Cotton has a relatively high degree of heat conductivity. Therefore it is, basically, a cool fiber. Cotton can be made into excellent summer clothing because it is a good conductor of heat. Crisp, clean, lightweight cotton fabrics look cool as well as feel cool. When warmth is required, cotton yarn made into napped or pile weave fabrics will have decreased heat conductivity, particularly if the fabric is compactly constructed.

Absorbency. The ease and extent to which moisture can penetrate into a fiber determines its absorbency. Once the outer protective cuticle of the cotton fiber is broken down by finishing processes, such as kiering and mercerizing, the fiber becomes very absorbent. Cotton fiber is composed primarily of cellulose, which is very absorbent. Its hollow center, or lumen, aids in conveying moisture. Such factors as the amount of twist in the yarn will also affect the absorbency, since a low-twisted yarn will be more absorbent than a high-twisted one. Fabric structure, such as a pile weave, will affect absorbency. Also, the compactness of the weave influences the absorbency becaus the looser the structure the more absor bent the fabric will be.

Cleanliness and Washability. Althou cotton attracts dirt particles because of roughness, this disadvantage is offset the washability of the fiber. Cotton f rics are not injured even in very hot wa with strong soaps or detergents; they la der well and withstand rough handlin

Reaction to Bleaches. As discusse Chapter 9, bleaches are chemical tions designed to remove discolor (and sometimes color). While hydrogen peroxide may be used, the more common household bleaches for cotton are solutions of sodium hypochlorite, such as Clorox, or sodium perborate, such as Snowy, which is a milder type. These bleaches, used as directed, will effectively bleach cotton fabrics. Bleach should be put into the rinse water after washing so that it is thoroughly mixed and diluted to avoid the oxidizing or yellowing that may be caused by overconcentration. Labels on wash-and-wear fabrics should be observed since some of these finishes are chlorine retentive—they turn yellow when subjected to sodium hypochlorite bleaches.

Shrinkage. When cotton fiber is wet, it tends to contract or shrink as it dries. As a result, cotton yarns and fabrics can shrink considerably, particularly those that are loosely constructed. However, preshrinking finishing processes, such as discussed in Chapter 9, minimize shrinkage in cotton fabrics. Labels should be read for the amount of residual shrinkage that a fabric or garment has and care instructions should be followed to retain the required size and shape.

Effect of Heat. Cotton will withstand moderate heat. If pressed with an iron that is too hot or if a hot iron is allowed to remain too long in one place on the fabric, it will scorch and ultimately burn. It is therefore best to either iron cotton material that has been dampened or use a steam iron.

Effect of Light. Cotton fiber oxidizes, turning yellow and losing strength from exposure to sunlight over a protracted period of time. Cotton fabrics should therefore be shaded from direct sunlight.

Resistance to Mildew. Cotton fabrics, especially sized fabrics, mildew readily when permitted to remain in a damp condition. Small greenish-black or rust colored spots caused by mildew fungus develop and a musty odor may be detected. Therefore, cotton material should be kept in a dry atmosphere. Where this is not possible, a mildew resistant finish or a mildew inhibitor is advisable when stored.

Resistance to Insects. Cotton is not digestible by moth larvae, so the fabric will not be attacked by moths. But in fabrics containing cotton and wool, the larvae may damage the cotton to get at the wool. Certain other insects that may be attracted to its cellulose content may damage cotton, but this is not common.

Reaction to Alkalies. Cotton is not harmed by alkalies. In fact, a solution of sodium hydroxide is used to mercerize cotton, making it stronger, smoother, and more lustrous.

Reaction to Acids. Cotton is not damaged by such volatile organic acids as acetic acid (vinegar). However, it is tendered if such nonvolatile organic acids as oxalic and citric (found in orange, lemon, and grapefruit juices) are allowed to remain on it, particularly if heat is also applied. They should therefore be rinsed with cool water as soon as possible. Concentrated cold or diluted hot mineral acids, such as sulfuric acid, will destroy cotton.

Affinity for Dyes. Cotton has a good affinity for dyes. It is dyed best with v[illegible] dyes, but oxidation bases, azoic, and reactive dyes may also be effectively used. Colorfastness is generally good, but specific conditions should be considered (s

Table 11-1). Fastness of dye to washing can be tested by washing a sample in hot water. Fastness to light can be tested by exposing a sample to light for a week or more. Penetration or thoroughness of dye can be tested by raveling a yarn and examining its unexposed surfaces.

Resistance to Perspiration. Perspiration may be alkaline or acidic, depending upon the individual's metabolism. Since cotton is resistant to alkali, alkali perspiration does not deteriorate cotton. However, acid perspiration has a slightly deteriorating effect. In either case, discoloration may occur.

COTTON BLENDS

Cotton is blended with many other fibers so that certain of the desirable properties of cotton, that other fibers may lack, will contribute to the general characteristics of the blended yarns and fabrics. As discussion of the properties of the other fibers proceeds, consideration will be given to the effect of cotton fiber when blended with each of these fibers, respectively.

REVIEW QUESTIONS

1. (a) What are the byproducts of the cotton plant? (b) For what are they used?
2. How would you judge cotton fabrics?
3. Name the more important varieties of cotton grown in the United States, according to their quality.
4. What climate is necessary for the growth of cotton?
5. Discuss the advantages of cotton fabrics.
6. How can cotton be made to simulate (a) linen, (b) wool, (c) silk?
7. (a) How may the strength of a fabric be determined? (b) How may the amount of sizing be determined?
8. (a) Why are long fibers separated from short fibers? (b)How may the consumer identify finished goods made from long staple?
9. Name some of the finishing processes used for cotton fabrics.
10. (a) What is ginning? (b) What are linters? (c) What are hulls?
11. Why is the more expensive method of vat dyeing used for such an inexpensive fiber as cotton?
12. What care should be taken when laundering cotton fabrics?
13. What characteristics can cotton contribute to blends or mixtures in yarns and fabrics?

SUGGESTED ACTIVITY

Obtain three samples of fabrics used cotton clothing. Attach to each a rec showing the name of the fabric, kind yarns, weave, thread count, and fin State the uses and relative durabilit each sample.

Chapter 14

LINEN

a natural cellulose fiber

Linen yarn is made from fibers removed from the stem of the slender flax plant. These fibers, held together under the stem's bark principally by a gummy substance (*pectin*), form the body of the flax plant. The flax fiber is composed basically of the substance, *cellulose*.

HISTORY OF LINEN

The fiber obtained from the stem of the flax plant was probably the first textile fiber to be used. Historical records show that linen cloth was produced and used far back in antiquity, the earliest record being the use of flax for fish nets by the Neolithic lake dwellers of the Stone Age. There is evidence that flax was used as a textile in 6000 and 4000 B.C. in the Middle East and Egypt. The oldest woven fabric dating from about 4100 B.C. was found in Fayum, east of the Nile Delta. The bodies of early Egyptian kings and nobles were swathed in yards of delicate linen, indicating that the art of spinning and weaving had reached a high state of perfection in that country 6000 years ago. Such linen burial wrappings have been found to be in good condition, proving the amazing durability of the flax fiber.

Linen has always been considered the fabric of luxury. In some ancient countries, linen was used only for ceremonial purposes, as the symbol of purity. The descriptive phrase "pure linen" is customarily used to describe all-linen fabrics. Linen always looks cool, crisp, and clean, and gives an attractive and immaculate appearance to the persons and objects it adorns.

Fine-quality linens still retain the reputation of luxuriousness and expensiveness. The flax plant must be grown in countries where there is plenty of cheap labor as well as natural facilities for extracting the fiber. Even the manufacture of the fiber into fabrics requires unusual care throughout each process to retain the strength and beauty of the fiber.

The seed of the flax plant is valuable as the source of *linseed oil*, which is used in the manufacture of paints, varnishes, linoleum, patent leather, and oiled silk. To obtain the seed, flax must be allowed to overripen. As overripening destroys the value of flax as a textile fiber, the method of raising the plant is influenced by the purpose for which it is required.

QUALITIES AND GRADES OF FLAX

The countries that produce flax of various grades are Australia, Austria, Belgium, Czechoslovakia, France, Germany, Ireland, The Netherlands, New Zealand, Poland, Scotland, and the U.S.S.R. Flax is grown in Canada and in the United States (Michigan, Minnesota, and Oregon), but chiefly for its seed.

Courtrai flax, which comes from the Lys district in Belgium, produces the finest and strongest yarns. The water of the Lys River in Belgium and of the Scheldt River in The Netherlands is free from minerals and has proved especially desirable for decomposing the woody tissues of the plant, a necessary step in treating the flax fiber.

Belgium has a reputation for producing the best quality of linen, but Ireland is noted for the best workmanship. Irish linen is also prized for its fine white color and strength. The flax is spun while it is wet, and the cloth is grass-bleached, two processes reserved for good-quality linen.

Scottish linen is lighter in color than Irish linen. It is used extensively in making heavy-grade fabrics, such as twine and canvases for tarpaulins.

French linen ranks high. It is characterized by fine designs and the use of round yarns, as the cloth is not put through the beetling process.

Russian flax is used for medium and coarse yarns, which are dark gray in color. Russian linen sometimes cracks because the fiber is not as carefully processed as in the countries that have a reputation for fine-linen production.

German linen is generally of medium grade. Austria, Czechoslovakia, and Poland also produce medium-quality flax.

FROM FIELD TO MILL

Cultivating

The flax plant requires deep, rich, well-plowed soil and a cool, damp climate. Prematurely warm weather affects the growth and the quality of the fiber. Level land with a plentiful supply of soft, fresh water is essential. As the soil in which flax is grown must be enriched for six years before it will yield a good harvest, only one crop in seven years can be raised on a specified portion of land. The crops, therefore, must be carefully rotated. Shorter periods of rotation have been tried with some success.

The flaxseeds are sown by hand in April or May. When the plants are a few inches high, the weeds must be pulled by hand with extreme care to avoid injury to the delicate sprouts. In three months, the plants become straight, slender stalks from 2 to 4 feet (60–120 cm) in height, with tapering leaves and small blue, purple, or white flowers. The plant with the blue flower yields the finer fiber. The others produce a coarse but strong fiber (see Figure 14-1).

Harvesting

By the end of August, the flax turns a brownish color, which indicates that the plant is about to mature; it is ready for harvesting. There must be no delay at this stage; otherwise, the fiber will lose its prized luster and soft texture. The plants are pulled out of the ground either by hand or efficiently by machine. If the

Figure 14-1 A close view of a field of flax in flower. Flax seeds are planted in the early spring, and mature to plants about three feet high after three to four months. The flax flower blooms for only about three days. *(Courtesy International Linen Promotion Association)*

stalk is cut, the sap is lost; this loss affects the quality of the fiber. The stalk must be kept intact, and the tapered ends of the fiber must be preserved so that a smooth yarn may be spun. The stalks are tied in bundles, called *beets* in preparation for extraction of the fiber (see Figures 14-2*a* and *b*).

Preparation of the Fiber

The seeds and the leaves are removed from the stems of the flax plant by passing the stalks through coarse combs. This process is called *rippling*. The bundles of plants are then steeped in water so that the tissue or woody bark surrounding the hairlike flax fiber will decompose, thus loosening the gum that binds the fiber to the stem. This decomposition is called *retting*.

Retting only loosens the woody bark. If flax is not retted enough, the removal of the stalk without injury to the delicate fiber is difficult. If flax is overretted, the fiber is weakened. The retting operation, as well as all other processes for

Figure 14-2 (*a*) The mature flax plant is about three feet high. Large machines harvest the plants by pulling them up from the roots; they are never cut. The stalks are bundled. (*b*) The bundles of flax stalks, called "beets," are stacked into "chapels" in the field for drying before the retting process begins. *(Courtesy International Linen Promotion Association)*

producing linen fabric, therefore requires great care.

Dew Retting. Dew retting is a method used in Belgium and the U.S.S.R. The flax straw is spread on the grass and is exposed to the atmosphere for three to four weeks. This method produces strong flax, dark gray in color.

Pool, or Dam, Retting. This method is used in Belgium and Ireland. It requires less time than dew retting, from ten to fifteen days. As stagnant pools of water are used, this method sometimes causes overretting, which is responsible for brittle and weak flax fibers. Pool retting darkens the flax, giving it a bluish gray color.

Stream Retting. This method for producing high-quality flax fiber was used extensively in the River Lys in Belgium but is now outmoded.

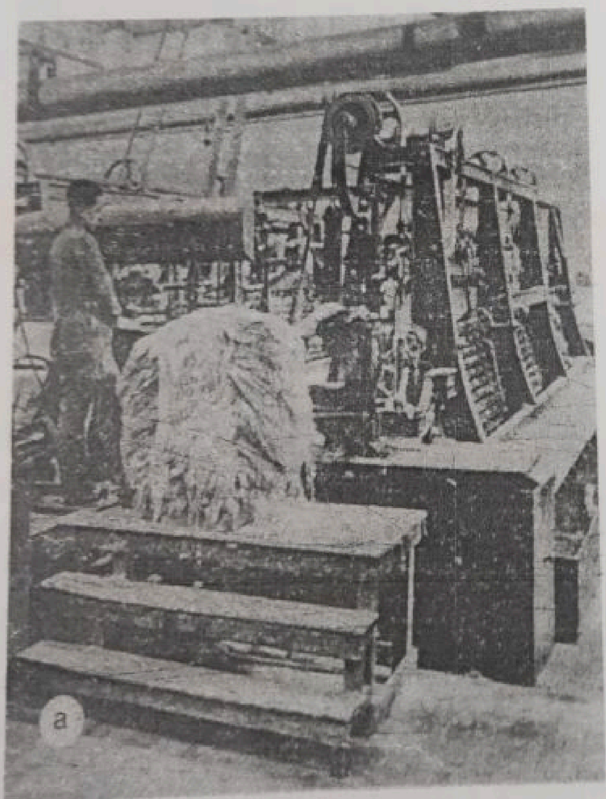
Vat, or Mechanical, Retting. This method shortens the retting process and is used primarily in Belgium, France, Northern Ireland, and the United States. The flax is immersed in wooden vats of warm water at temperatures ranging from 75 to 90°F (25–30°C), which hastens the decomposition of the woody bark. The flax is removed from the vats and passed between rollers to crush the decomposed bark as clean water flushes away the pectin, or gum, and other impurities. Linen produced by this method is more susceptible to mildew.

Chemical Retting. Chemical retting can shorten the retting process, but chemicals will affect the strength and color of the flax fiber. Soda ash, oxalic soda, and caustic soda in warm water, or boiling in a dilute sulfuric acid solution are the chemical methods used.

MANUFACTURING PROCESSES

Breaking

The stalk becomes partially separated from the fiber when the wet plants are placed in the fields to dry (Figures 14-3*a* and *b*). When the decomposed woody tis-



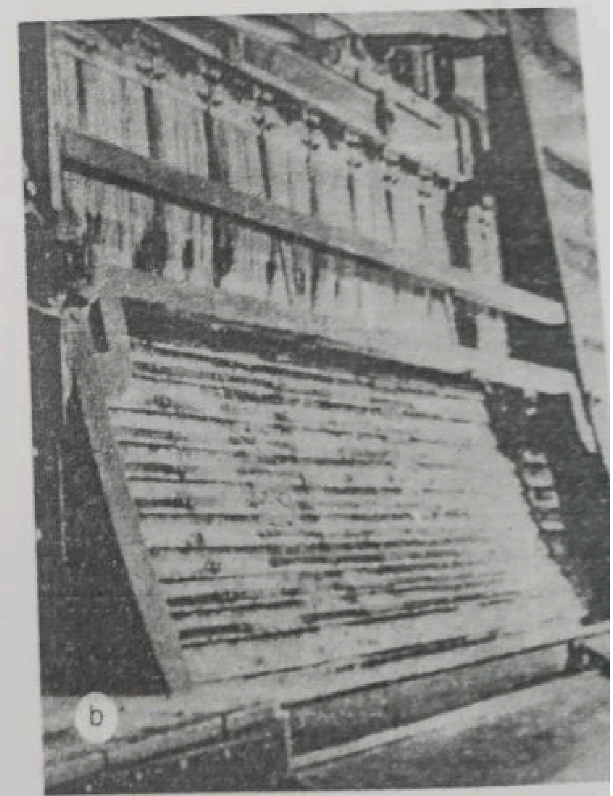


Figure 14-3 (*a*) Scutching separates flax fibers from the hard wooden core of the stalk by drying and grindin[g]. Long "line" fibers and short "tow" fibers freed by scutching are then combed to cleanse and straight[en] them. (*b*) Close-up of the suspended hanks of flax being hackled by the horizontal rows of combs t[hat] pass down behind them. *(Courtesy Irish Linen Guild)* sue is dry, it is crushed by being passed through fluted iron rollers. This *breaking* operation reduces the stalk to small pieces of bark called *shives*.

Scutching

The scutching machine removes the broken shives by means of rotating wooden paddles, thus finally releasing the flax fiber from the stalk. This operation can be done by hand as well as by machinery.

Hackling (Combing)

The simple combing process known as hackling straightens the flax fibers, separates the short from the long staple, and leaves the longer fibers in parallel formation. For very fine linen, hackling is done by hand. For faster and more efficient combing, hackling is done by machine. A finer comb is used progressively at each stage (see Figures 14-3 and 14-4).

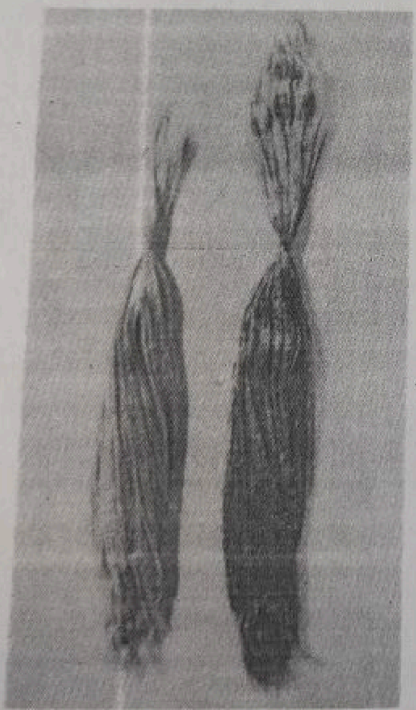


Figure 14-4 Emerging from the combing process, these long wisps of fiber have passed over a series of graduated metal pins in the combing machine and now resemble switches of human hair. The fiber at the left was retted in water; the fiber at the right was field retted. *(Courtesy International Linen Association).*

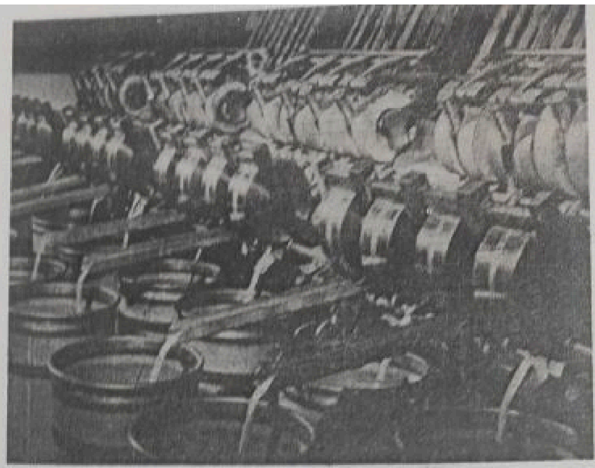


Figure 14-5 Hanks of combed flax pass through a drawing machine where they emerge in a continuous wide ribbon called a "sliver." Repetition draws the flax strands thinner until all the fibers lie parallel for spinning. *(Courtesy International Linen Promotion Association.)*

Spinning

The short-staple flax fibers, called *tow*, are used for the spinning of irregular linen yarns. Tow is put through a carding operation, similar to the carding of cotton staple, which straightens the fibers and forms them into a sliver ready for spinning into yarn. The long-staple fibers are used for fine linens. These are called *line*, sometimes *dressed flax*. Line fibers are from 12 to 20 inches (30–50 cm) in length. They are put through machines, called *spreaders*, which combine fibers of the same length, laying them parallel so that the ends overlap. The sliver thus formed passes through sets of rollers, making a rove for the final spinning process, which inserts the necessary twist (see Figure 14-5).

The standard measure of flax yarn is the *cut*. If 1 pound of flax fiber is drawn out to make 300 yards, the yarn is known as Ne 1. When drawn out to make twice 300 yards, it is labeled Ne 2. The higher the yarn count, the finer the yarn. Exceptionally fine linen yarns for fine laces have been spun as high as 600s (2.7 tex). (For conversion to the tex system, see Table 2-1.)

Although flax is one of the strongest fibers, it is inelastic and requires a carefully controlled, warm, moist atmosphere for both methods of spinning.

Dry Spinning. Dry spinning does not use moisture. It produces rough, uneven yarns, which are not especially strong. These yarns are used for making coarse, heavy, and inexpensive linen fabrics.

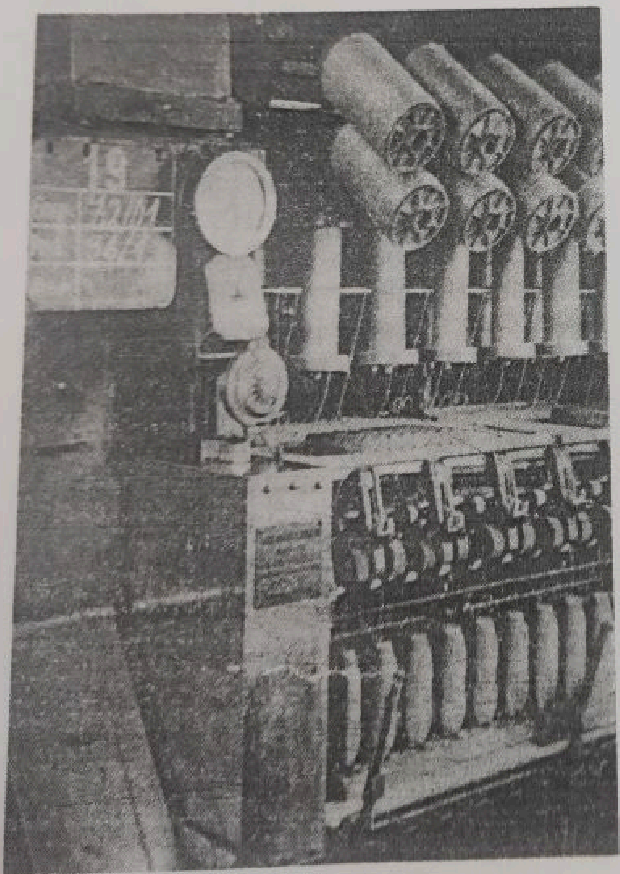


Figure 14-6 Once spun, the yarns are wound on bobbins to be used to weave cloth. Yarns for fine or sheer fabrics are spun by a wet process, while fibers for heavier fabrics are spun dry. *(Courtesy International Linen Promotion Association).*

Wet Spinning. This method requires a temperature of 120°F (50°C), which is conducive to the production of soft, fine, even yarns. By passing the roving through hot water, the gummy substance on the fiber is dissolved, permitting drawing out the roving into a fine yarn of high yarn count (see Figure 14-6).

CONSTRUCTION OF LINEN FABRICS

The inelasticity of the flax fiber presents a problem in the weaving process because the fiber breaks easily under strain. A dressing, applied to the warp yarns by passing them over rotating brushes, helps linen yarns to withstand the strain of being lifted by the heddles during weaving. A very moist atmosphere is also required.

Linen yarns are generally not knitted because of their inherent stiffness and resistance to being formed into loops. Special surface treatment of the yarns, which must be uniform and of high count, and specialized knitting machines would be required. However, research has demonstrated that linen fiber properly blended with manmade fibers can produce yarns that can be knitted into fabrics having certain advantageous features contributed by the respective fibers.

General Applications

Linen fabrics usually have a balanced or squared construction, with the exception of double damask and certain sheer linens. The thread count, therefore, is always expressed as one number.

Linen has long been used for a wide variety of apparel and home furnishings. In fact, the oft-used term of "linens," which refers to such home furnishings as sheets, pillowcases, towels, tablecloths, and napkins, now usually made of cotton and cotton blends, stems from their original composition of linen. Linen is now used to a very limited extent. Fabrics for apparel are usually made of plain or basket weaves. Twill weaves are used for drill fabrics, drapery, and wall coverings. Damasks for tablecloths and drapery are made in Jacquard patterns using satin weaves (see Chapter 31).

FINISHING PROCESSES

Linen is generally scoured before it is given a finish, and the finish used depends upon the intended purpose and use of the fabric. The most common treatment given to linen is bleaching.

Bleaching

Linen is usually bleached in the piece except when it is to be used for such purposes as yarn-dyed fabrics and dress linen. The two methods used are *grass bleaching* and *chemical bleaching*.

Grass bleaching produces the finest results. It is accomplished by spreading the linen out in the fields so that it is gradually bleached in the sun. This process is time-consuming but less injurious to the linen; it is therefore considered more desirable.

Although chemical bleaching is the method chiefly used, it may adversely affect the durability of the finished fabric owing to the weakening effects of the chemicals. The process requires boiling the linen in a lime solution for eight to ten hours to remove such impurities as wax, then rinsing it in water, bleaching it with hydrochloric acid, washing the fabric again, and then, finally, treating it with caustic soda to neutralize any acid that still remains.

Bleaching produces four grades in the finished product: fully bleached, three-quarters bleached, half or silver bleached, and quarter bleached. Unbleached linen makes a fifth grade. A fully bleached linen fabric is less enduring than any other grade. Unbleached linen is the strongest because the natural strength of the fiber has not been weakened by the bleach. It is sometimes called gray linen or brown linen.

Other Processes

The natural characteristics of linen are enhanced by the following finishing processes, which are discussed in detail in Chapters 9 and 10.

Beetling—for flexibility and uniform thickness

Calendering—for luster and smoothness

Mercerizing—for luster

Sizing—for added body

Wrinkle resisting—for resilience and easier care

Linen is never napped. The fiber does not lend itself to this process, nor would napping be desirable for long-staple yarns of hard surface. Where some crease resistance is obtained by reducing the yarn to short staple, the strength of the linen, which is its chief attribute, is sacrificed. Thus, any fuzziness in a linen fabric indicates the use of short staple or the presence of another fiber.

DYEING LINEN

Linen is seldom yarn-dyed. The surface of the natural flax fiber is hard and non-porous and is, therefore, impenetrable t dyes. The cells of the fiber are held together with tissue that can be broken down only in a severe bleaching process. Highly colored linens, therefore, will not give lasting service because they must have been fully bleached to absorb the dye. The colors are therefore usually pastel or dark but dull shades.

EVALUATING LINEN FABRICS

Reference has already been made to the general use of the term "linen" for a variety of household goods. Therefore, when a consumer does want articles made of linen, the fiber identification should be noted. The Federal Trade Commission requires that a fabric may be labeled "linen," "pure linen," or "pure flax" only if it is made of 100 percent linen. A fabric that contains linen and other fibers must be so labeled, indicating the percentage of each fiber used in the order of weight predominance. However, fabrics made of fibers other than linen, such as rayon, but made to resemble linen may be labeled by such terms as "rayon linen."

Even when a fabric is labeled "pure linen," it is best to know whether the yarns are line or tow. Fine linen fabrics, such as high-grade table damask and dress linens, are usually made of line, the long uniform staple. Line may be distinguished from tow by untwisting and examining the length of the fibers.

Pure linen is free from lint; therefore, the presence of lint indicates adulteration with cotton, or possibly oversizing. Cotton yarns are frequently mixed with linen to produce inexpensive fabrics. The name Union Linen is given to a fabric of which half or more is cotton. Linene is a name for an all-cotton fabric that simulates linen.

Strength. Linen is especially durable being two to three times as strong as cotton. Among the natural fibers, it is second in strength to silk. In linen, weight may be considered a criterion of durability. Damask weighs from 4 to 7 ounces to the square yard (135–235 g/m²).

Elasticity. Linen has no significant elasticity. It is, in fact, the least elastic of natural fibers. In order to fit comfortably, linen garments should neither bind nor pull at the seams.

Resilience. Linen fiber is relatively stiff and has little resilience. Therefore, it wrinkles easily, which somewhat offsets its otherwise excellent qualities as a fabric for summer apparel. But it is possible to buy dress linens that have been given one of the wrinkle-resistant processes described in Chapter 10.

Due to its stiffness, linen fabrics should not have creases pressed firmly into them. Deep repeated folds, as in tablecloths, should be avoided because these creases eventually cause the otherwise strong yarns to crack and break long before they ordinarily would.

Drapability. Linen has more body than cotton and drapes somewhat better.

Heat Conductivity. Linen is most suitable for summer apparel, as it allows the heat of the body to escape.

Absorbency. When absorbency is the main consideration, linen is preferable to cotton. It absorbs moisture and dries more quickly. It is therefore excellent for handkerchiefs and towels.

Cleanliness and Washability. Linen launders well and gives up stains readily;

its softness is enhanced by repeated washings. Because of its stiffness, linen must be thoroughly damp when it is ironed, or a steam iron may be used. Some linen apparel requires dry cleaning because of construction and fabric finish (or lack thereof). Care label instructions should be observed.

Reaction to Bleaches. Linen does not stain as readily as cotton, but it is also more difficult to bleach. Like cotton, it is weakened by sodium hypochlorite bleaches. Sodium perborate bleaches are effective and safer.

Shrinkage. Linen does not shrink a great deal; in fact, it shrinks less than cotton. But preshrinkage finishing is desirable.

Effect of Heat. Linen scorches and flames in a manner similar to cotton.

Effect of Light. Linen is more resistant to light than cotton, but it will gradually deteriorate from protracted exposure.

Resistance to Mildew. Like cotton, linen is vulnerable to mildew.

Resistance to Insects. Like cotton, linen is not damaged by moths. Damage by other insects is uncommon.

Reaction to Alkalies. Linen, like cotton, is highly resistant to alkalies. Linen may also be mercerized.

Reaction to Acids. Linen is damaged by hot dilute acids and cold concentrated acids—but not by cold dilute acids.

Affinity for Dyes. Linen does not have good affinity for dyes. However, it is possible to obtain dyed linen that has good colorfastness. When buying colored linens, look for the words "Guaranteed Fast Color" on the label or get a guarantee of colorfastness from the store. If a label states that the fabric is vat-dyed, it has been given the fastest color possible to withstand washing.

Resistance to Perspiration. Acid perspiration will deteriorate linen. Alkali perspiration will not cause deterioration. But in either case discoloration may occur.

LINEN BLENDS

Linen fiber is blended with other fibers so that certain of its desirable properties, that other fibers may lack, will contribute to the general characteristics of the blended yarns and fabrics. One may sometimes find on a linen blend fabric the trademark, Linron, which identifies linen fiber that has been put through a series of mechanical and chemical processes that produce crimped, prebleached, preshrunk linen fiber intended for spinning on cotton or woolen systems. Since there has been discussion of the properties of cotton and linen, consideration can now be given to their blending. After discussion of the properties of other fibers in later chapters, blending of linen with each of them will be considered when significant and appropriate.

Linen and Cotton

As with any blend, the amount of each fiber used is significant in its contributing effects. In any event, linen offers prestige. It also provides body and improves drapability. Linen adds greater strength and absorbency. Cotton is very compatible with linen. It spins well with it to provide good quality yarn and fabrics while keeping the cost lower than it would be in an all-linen material.

Chapter 17

MINOR NATURAL FIBERS

vegetable and mineral fibers

The textile industry uses other natural fibers in addition to those already studied. Each has its field of usefulness. Some have qualities that make them suitable for purposes that none of the fibers previously discussed could fulfill satisfactorily. Others can be used as acceptable substitutes or even adulterants, as long as the finished goods fulfill the purpose for which they are intended and the selling price is in line with the value of the product.

VEGETABLE FIBERS

Jute

Jute is a natural fiber obtained from a tall plant of the same name. It is grown throughout tropical Asia, chiefly in India and Bangladesh, for commercial uses. The plant is easy to cultivate and harvest. The fiber is obtained by retting, similarly to flax. The fine, silklike fiber is easy to spin but is not durable, as it deteriorates rapidly when exposed to moisture. Jute is the cheapest textile fiber and is used in great quantities. Because of its lack of strength, jute is difficult to bleach and can never be made pure white. It can be converted into a wool-like fiber by treatment with a strong caustic soda.

Though jute is often used as an adulterant with other fibers, it can be easily recognized when tested for its marked sensitivity to mineral acids. Concentrated mineral acids readily dissolve jute. Dilute mineral acids rot it quickly. It is especially weak in salt water. Jute is used as a substitute for hemp, as binding threads for carpets and rugs, as rug cushions, as a filler with other fibers, and as a linoleum base. It is made into coarse, cheap fabrics, such as burlap novelty dress goods and heavy bagging.

Kapok

Kapok is a natural fine, white hairlike fiber obtained from the seed capsules of plants and trees grown in Java, Kalimantan (formerly Borneo), Sumatra, and Central America. It is sometimes called *silk cotton* because its luster is almost equal to that of silk. Kapok resembles cotton in general appearance but is always of shorter average staple—less than 1 inch (25 mm). Under the microscope, kapok can be easily distinguished from cotton, as it appears to be a hollow tube with very thin walls and frequent folds but no twist.

The smooth texture and weakness of kapok prevents its being spun into yarn, but it is used in mattresses, cushions, upholstered furniture, and life preservers. Kapok is buoyant, but with continued use has a tendency to mat and become lumpy. This condition can be improved if articles in which kapok has been used are aired and put in the sun at frequent intervals. Kapok is resistant to vermin and is especially resistant to moisture, drying quickly when wet. It is adaptable for articles that are constantly exposed to moisture. Kapok is also used for soundproofing and for insulating.

Ramie

Ramie is a natural woody fiber resembling flax. Also known as *rhea* and *China grass*, it is obtained from a tall shrub grown in Southeast Asia, China, Japan, and southern Europe. The fiber is stiff, more brittle than linen, and highly lustrous. It can be bleached to extreme whiteness. Ramie lends itself to general processing for textile yarns, but its retting operation is difficult and costly, making the fiber unprofitable for general use. When combed, ramie is half the weight of linen, but much stronger, coarser, and more absorbent. It has permanent luster and good affinity for dyes; it is affected little by moisture. Ramie is used as filling yarn in mixed woolen fabrics, as adulteration with silk fibers, and as a substitute for flax. The China-grass cloth used by the Chinese is made of ramie. This fiber is also useful for rope, twine, and nets.

Hemp

Some thirty varieties of hemp, another tall plant with a natural woody fiber, are grown in nearly all the temperate and tropical countries of the world. All these varieties resemble one another in general appearance and properties, but only those having fibers of high tensile strength, fineness, and high luster have commercial value. Hemp must pass through a retting process and subsequent manufacturing operations similar to those used for flax. It resembles flax closely, and its fiber is easily mistaken for linen. Hemp is harsh and stiff and cannot be bleached without harm to the fiber. As hemp is not pliable and elastic, it cannot be woven into fine fabrics. Hemp is durable and is used in rug and carpet manufacturing. It is especially suitable for ship cordage as it is not weakened or rotted by water. Central American hemp is chiefly used for cordage. "Manila hemp" is a fiber from the leaves of the abaca plant; it is very strong, fine, white, lustrous and, though brittle, it is adaptable for the weaving of coarse fabrics.

Sisal

Sisal is a natural fiber obtained from the leaves of a plant that resembles cactus, grown in Africa, Central America, the West Indies, and Florida (see Figure 17-1). The best supply is produced in Yucatan, where it is known as *henequen*. The smooth, straight fiber is light yellow in color. Sisal is used for the better grades of rope, for twine, for the bristles of

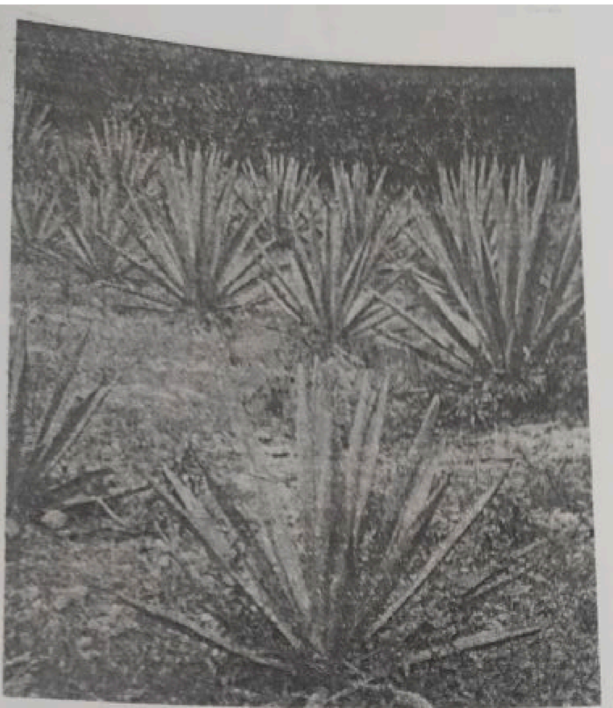


Figure 17-1 The strong sisal fiber, obtained from the leaves of the agave, has long been used for rope. Now, however, it is receiving competition from polypropylene fiber. *(Courtesy H. Hodge)*

inexpensive brushes, and as a substitute for horsehair in upholstering. Sisal may be mixed with hemp, but it should not be used for ship cordage because it disintegrates in salt water.

Coir

This natural coarse brown fiber is obtained from the husk of the coconut. It is stiff but elastic. Because of its resemblance to horsehair, it is used for stuffing upholstered furniture. Coir is also suitable for cordage, sailcloth, and coarse mattings.

Piña

Piña, or pineapple fiber, is obtained from the large leaves of the pineapple plant grown in tropical countries. This natural fiber is white and especially soft and lustrous. In the Philippine Islands, it is woven into piña cloth, which is soft, durable, and resistant to moisture. Piña is also used in making coarse grass cloth and for mats, bags, and clothing.

ASBESTOS

Asbestos is a natural fiber obtained from varieties of rocks found in Italy, South America, and Canada. It is a fibrous form of silicate of magnesium and calcium, containing iron, aluminum, and other minerals (see Figure 17-2). The soft, long, glossy white fibers are pressed into sheets; and the best quality can be spun into yarn. Chrysolite asbestos is the most valuable for the latter purpose, as it has a fine, long staple that has strength and flexibility. Asbestos yarns are always made as ply yarns to increase their tensile strength. Asbestos will not burn, but it will melt at a sufficiently high temperature. It is acidproof and rustproof.

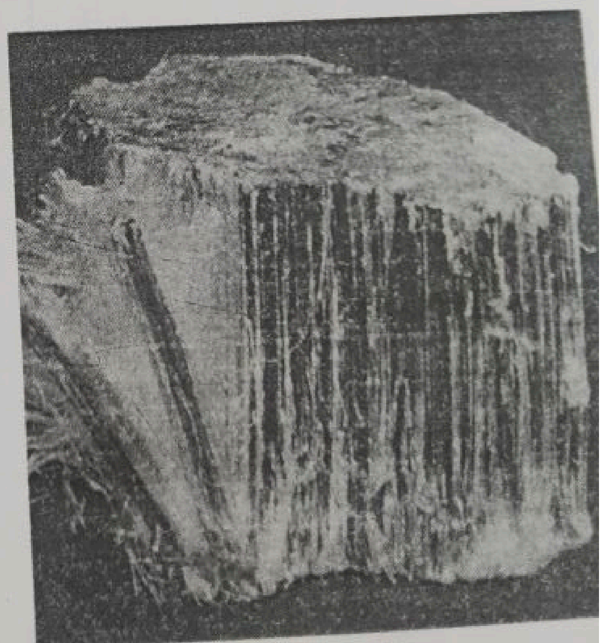


Figure 17-2 Asbestos rock is manufactured i asbestos fiber. *(Courtesy Johns-Manville Corp.)*

Asbestos has been used in making firefighting suits and fire-resistant fabrics, and in fireproof materials of many types—theater curtains, draperies, shingles, tiles, auto brake lining, andiron holders, and partitions. It is spun around copper wire and wrapped around pipes and joints of high-pressure steam engines. Inferior grades are used for soundproofing. However, asbestos has been found to be hazardous to health, as particles can lodge in the respiratory system and are carcinogenic. Its processing and use, therefore, must be carefully controlled.

REVIEW QUESTIONS

1. For what purposes are the minor natural fibers generally used?
2. Name five minor fibers, and give one use for each.
3. Why is jute never available in a pure white color?
4. Why is kapok never woven?
5. How does kapok differ from cotton?
6. Compare ramie with linen.
7. Why is hemp suitable for cordage?
8. Describe the qualities of asbestos, its uses, and limitations.

Chapter 15

WOOL AND HAIR

natural protein fibers

Wool fiber and hair fiber are the natural hair growth of certain animals and are composed of *protein*.

HISTORY OF WOOL AND HAIR

Originally, wool was borne on wild species of sheep as a short, fluffy undercoat concealed by hair. When wild sheep were killed by primitive people for food, they used the pelts as body coverings. The fluffy undercoat probably became matted by usage, thus giving early man the idea of felting it into a crude cloth. It is believed that ancient shepherds in the first century A.D. discovered that Merino sheep could be bred to improve the fleece.

At first, wool was a very coarse fiber. Its development into the soft, fleecy coat so familiar on domesticated sheep is the result of long-continued selective breeding. The breeding of the animals and the production of the wool fiber into fabric are more costly processes than the cultivation of plant fiber and its manufacture. Consequently, wool fabrics are more expensive than cotton and linen. But wool provides warmth and physical comfort that cotton and linen fabrics cannot give. These qualities, combined with its soft resiliency, make wool desirable for apparel as well as for such household uses as rugs and blankets.

Hair fibers have all the qualities of wool and, in general, are even more expensive than wool. Vicuña is the world's costliest textile product and surpasses all other wool and hair fibers in fineness and beauty. These hairs are sometimes mixed with wool, adding rather than detracting from the quality of any wool fabric in which they appear.

It will be noted that the fibers discussed here are removed from the skins of the animals by some appropriate means in order to be converted into yarns and fabrics. When the entire skin, or hide, is removed from a dead animal, it may be dehaired and tanned to make leather or if, as is sometimes done with sheepskin, the wool may be sheared to a predetermined height and the hide is then converted into leather with the wool fleece surface retained for such purposes as coats.

The [illegible] general [illegible]. Cold [illegible] heavier fiber. Excessive moisture dries out natural grease. Insufficient or poor food retards growth. Certain countries are suitable for large-scale sheep raising and consequently produce the greatest quantities of wool. The chief wool-producing countries are Australia, the U.S.S.R., New Zealand, Argentina, South Africa, Uruguay, and the United States.

CLASSIFICATIONS FOR WOOL

Classification by Sheep

There are about forty breeds of sheep. Counting the crossbreeds, there are over 200 distinct grades of sheep. Those that produce wool may be classified into four groupings according to the quality of the wool produced.

Merino Wool. Merino sheep produce the best wool (see Figure 15-1*a*). The variety originated in Spain and was so prized for its outstanding quality that during the Middle Ages it was a capital offense to export a Merino sheep from Spain. The staple is relatively short, ranging from 1 to 5 inches (25–125 mm), but the fiber is strong, fine, and elastic and has good working properties. Merino fiber has the greatest amount of crimp of all wool fibers and has a maximum number of scales, totaling as many as 3000 to the inch (118/mm)—two factors which contribute to its superior warmth and spinning qualities. Merino is used in the best types of wool clothing. The Ohio Merino, Austrian Silesian, and French Rambouillet are all varieties of Merino sheep. Other types are now found in Australia, New [illegible], South America, South Africa, and Spain.

Class-Two Wools. This class of sheep originated in England, Scotland, Ireland, and Wales. They helped make the British Isles famous for their fine wool fabrics. They are, however, no longer limited to that area and are now raised in many parts of the world. While not quite as good as the Merino wool, this variety is nevertheless a very good quality wool. It is 2 to 8 inches (50–200 mm) in length, has a large number of scales per inch, and has good crimp. The fibers are comparatively strong, fine, and elastic and have good working properties. Some of the better-known sheep of this variety include Bampton, Berkshire, Blackface, Cornwall, Devonshire, Dorset, Hampshire, Hereford, Exmoor, Kent, Norfolk, Shropshire, Southdown, Sussex, Oxford, Welsh Mountain, Wiltshire, Westmoreland, Irish, and Ryeland (see Figure 15-1*b*, *c*, *d*).

Class-Three Wools. This class of sheep originated in the United Kingdom. The fibers are about 4 to 18 inches long (100–455 mm), are coarser, and have fewer scales and less crimp than Merino and the class-two wools. As a result, they are smoother, and therefore have more luster. These wools are less elastic and resilient. They are nevertheless of good enough quality to be used for clothing. In fact, some of these sheep, such as Leicester, Cotswold, Cheviot, Harris, Lewis, and Shetland, have given their names to wool fabrics. (See Figure 15-1*e*.)

Class-Four Wools. This class is actually a group of mongrel sheep sometimes referred to as half-breeds. The fibers are from 1 to 16 inches (25–400 mm) long, are coarse and hairlike, have relatively few scales and little crimp, and are therefore smoother and more lustrous. This wool is less desirable, with the least elasticity and strength. It is used mainly for carpets, rugs, and inexpensive low-grade clothing.

Classification by Fleece

Sheep are generally shorn of their fleeces in the spring, but the time of shearing varies in different parts of the world. In the United States, shearing takes place in April or May; in Australia, in September; in Great Britain, in June or July. Texas and California sheep are shorn twice a year because of the warm climate.

Sheep are not washed before shearing. Sometimes, they are dipped into an antiseptic bath, but this is done only when prescribed by law. Formerly, sheep were shorn with hand clippers; today the fleeces are removed in one piece by machine clippers, which shear closer as well as faster.

A skilled worker can shear up to 200 sheep a day. Traveling by truck from southwestern United States in the early spring, shearers work their way to the northern ranches and then south again.

Wool shorn from young lambs differs in quality from that of older sheep. Also, fleeces differ according to whether they come from live or dead sheep, which necessitates standards for the classification of fleeces.

Lamb's Wool. The first fleece sheared from a lamb about six to eight months old is known as *lamb's wool* and sometimes referred to as *fleece wool*, or *first clip*. This wool is of very fine quality; the fibers are tapered because the ends have never been clipped. Such fibers produce a softness of texture in fabrics that is characteristic only of lamb's wool. Because of its immaturity, however, lamb's wool is not as strong as fully developed wool of the same sheep.

Hogget Wool. Hogget (hogg or teg) wool comes from sheep twelve to fourteen months old that have not been previously shorn. The fiber is fine, soft, resilient and mature, and has tapered ends. Hogget wool is a very desirable grade of wool and, because of its strength, is used primarily for the warp yarns of fabrics.

Wether Wool. Any fleece clipped after the first shearing is called *wether wool*. This wool is usually taken from sheep older than fourteen months, and these fleeces contain much soil and dirt.

Pulled Wool. When sheep are slaughtered for meat, their wool is pulled from the pelt by the use of lime, by sweating, or by a chemical depilatory. Such wool fiber, called *pulled wool*, is of inferior quality for two reasons: (1) because sheep that are raised for meat generally do not have a good quality of wool, (2) because the roots of the fibers are generally damaged by the chemicals and the tension exerted in pulling.

Dead Wool. The wool fiber known as *dead wool* is sometimes mistaken for pulled wool. The term is correctly used for wool that has been recovered from sheep that have died on the range or have been accidentally killed. Dead wool fiber is decidedly inferior in grade; it is used in low-grade cloth.

Cotty Wool. Sheep that are exposed to severe weather conditions or lack of nourishment yield a wool that is matted or felted together and is hard and brittle. This very poor grade is known as *cotty wool*.

Taglocks. The torn, ragged, or discolored parts of a fleece are known as *taglocks*. These are usually sold separately as an inferior grade of wool.

[illegible] recovered from old clothing, rags of all kinds, and waste from wool manufacturing; all are important sources. This wool is variously called salvaged, reclaimed, reworked, or remanufactured, but it is best known in the textile industry as *shoddy*. This term is misunderstood by the average consumer, who is inclined to believe that wool fabric containing remanufactured fibers is necessarily of inferior quality. This is not so.

The hardier, though less resilient, remanufactured fibers, when obtained from good original stock and combined with new wool from lamb, hogget, or wether fleeces, add durability to the soft new wool. Thus, remanufactured fibers contribute ability to withstand hard wear, although there is some sacrifice in warmth, softness of texture, and resiliency. They also make wool clothing available to consumers who cannot afford expensive wool fabrics.

To correct wrong impressions concerning the use of remanufactured wool, and also to protect consumers against unscrupulous practices, the U.S. government passed the Wool Products Labeling Act in July, 1941. This act, amended in 1980, provides that every article of wool clothing must be labeled according to the type of wool used in its manufacture. The label must state: (1) the amount of wool fiber in the fabric, (2) the percentage by weight of new, or virgin, wool fibers, (3) the percentages of recycled fibers in the fabric, (4) the percentage of each fiber other than wool, if such fibers constitute 5 percent or more of [illegible]

[illegible] the law does not require labeling as to the type of sheep or the type of fleece from which the wool has come. The information on the labels is therefore of only limited value to the consumer.

Wool

The simple term "wool," according to government standards, must always mean new wool that has not been made up in any form of wool product. New wool comes directly from a fleece. It has never been previously spun, woven, felted, or worn.

The term "virgin wool" is now used by the textile industry to designate new wool from a sheep's fleece, but the term is too all-inclusive to serve as a criterion of quality. Although the term testifies to the fact that virgin wool does not contain recycled wool fibers, it can be used to identify the less desirable fibers of a fleece as well as a specially fine quality of wool. Virgin wool may also include pulled or dead wool, which may be of definitely inferior stock. One should not consider that a fabric labeled "100 percent new wool" is necessarily more serviceable than one containing any of the recycled wool fibers, for there are many different grades of new wool. It is important to remember that a high grade of recycled wool makes a more serviceable fabric than one having a low grade of new wool.

Two other terms widely used on labels are "pure wool" and "wool blend," both registered certification marks of the Wool Bureau, Inc. (See Figures 15-2*a* and *b*.)

The standard for wool grading in the United States is based upon the quality of wool produced by the Merino sheep because it yields the finest-quality wool in terms of diameter, scales, and crimp. For example, first-quality wool is identified as *fine* and is equivalent to the quality of wool that could be obtained from a full- to three-quarter-blood Merino sheep; second quality is equivalent to the kind of wool that could be obtained from a half-blood Merino. The poorest qualities are identified as *common* and *braid*; they are coarse, have little crimp, relatively few scales, and are somewhat hairlike in appearance.

The grading system on the world market is based upon the British numbering system, which relates the fineness, or diameter, of the wool fiber to the kind of combed, or worsted, yarn that could be spun from 1 pound of scoured wool. For example, the first in quality would be that wool which is fine enough for and capable of being spun from 1 pound of fiber into the highest wool yarn counts of 80s, 70s, and 64s (see page 275 for explanation of wool yarn count). The second in quality is fine enough to be capable of being spun into yarn counts of 62s, 60s, and 58s. The poorest grade is that wool which is capable of being spun into yarn counts of only 40s and 30s. An equivalent grading scale of the British and United States systems is shown in Table 15-1.

Garnetting. Recycled wool fibers are obtained by separately reducing the unused and used materials to a fibrous mass by a picking and shredding process called *garnetting*. The fibers are then put through a dilute solution of sulfuric or hydrochloric acid, which destroys any vegetable fibers that may be contained in the raw stock. This process is known as *carbonizing*, and the resultant wool fibers are called *extracts*. The new staple ranges from ¼- to 1½-inch (6–40 mm) lengths.

TABLE 15-1 [illegible]

UNITED STATES SYSTEM	[illegible]
Fine (full- to three-quarter blood)	[illegible]
Half-blood	[illegible]
Three-eighths-blood	56s
Quarter-blood	50s, 48s
Low-quarter-blood	46s
Common	44s
Braid	40s, 36s

The quality and cost of recycled wool fibers depend on the original stock from which they were obtained. A good grade of recycled wool may cost 5 times as much as a poor grade of virgin wool.

Scouring. The next step in preparing raw wool for manufacturing is a thorough washing in an alkaline solution; this process is known as *scouring*. The scouring machines contain warm water, soap, and a mild solution of soda ash or other alkali; they are equipped with automatic rakes, which stir the wool. Rollers between the vats squeeze out the water. If the raw wool is not sufficiently clear of vegetable substance after scouring, it is put through the carbonizing bath of dilute sulfuric acid or hydrochloric acid to burn out the foreign matter.

For some consumers' goods, the term "naphthalated wool" is used, which means that the grease and dirt found in the fleece when originally sheared from the sheep's back have been removed by a series of naphtha baths followed by clear water to

remove the naphtha. When wool has been thus treated by a cleansing agent, dyestuff penetrates better. For some purposes, wool is degreased by extracting the grease with a solvent, such as perchloroethylene. Excess solvent is evaporated off and recovered, and the wool is ready for further processing. This method is used both on stock and piece goods.

Drying. Wool is not allowed to become absolutely dry. Usually, about 12 to 16 percent of the moisture is left in the wool to condition it for subsequent handling.

Oiling. As wool is unmanageable after scouring, the fiber is usually treated with various oils, including animal, vegetable, and mineral, or a blend of these to keep it from becoming brittle and to lubricate it for the spinning operation.

Dyeing

If the wool is to be dyed in the raw stock, it is dyed at this stage. The advantage of stock dyeing has been described in Chapter 11. Some wool fabrics are piece-dyed, some are yarn- or skein-dyed, and some are top-dyed.

Blending

Wool of different grades may be blended or mixed together at this point. It is not uncommon for taglocks and inferior grades of wool to be mixed with the better grades. The use of a mixture with a coarser grade of fiber is a legitimate practice if the purpose is to make a hardier product and a less expensive one, provided the label on the finished goods indicates a true description of the raw materials used. Subsequent to wool grade blending, other fibers may be blended with the wool (see page 283).

Carding

The carding process [illegible] of woolen yarns and worsted yarns. Manufacturing processes from this point on depend on whether the wool fiber is to be made into a woolen or worsted product (see Figures 15-4 and 15-5).

In the manufacture of woolen yarns, the essential purpose of carding is to [illegible] entangle the fibers by passing the wool fibers between rollers covered with thousands of fine wire teeth. Incidentally, this action also removes some dirt and foreign matter from the fibers. As the wool fibers are brushed and disentangled by these wires, they tend to lie parallel, which would make woolen yarns too smooth. Since woolen yarns should be somewhat rough or fuzzy, it is not desirable to have the fibers too parallel. By use of an oscillating device, one thin film, or sliver, of wool is placed diagonally and overlapping another sliver to give a crisscross effect to the fibers. This permits the fibers to be disentangled and somewhat parallel and at the same time provides a fuzzy surface to the yarn. After this process, the woolen slivers go directly to the spinning operation.

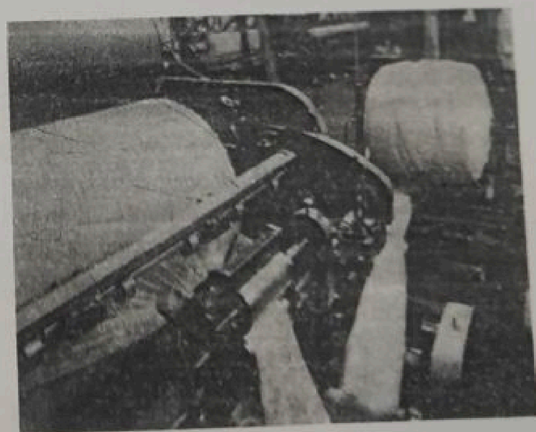


Figure 15-4 Carded wool in fine web form is drawn from the cylinder (left) into woolen sliver (right). *(Courtesy National Association of Wollen Manufacturers)*

remove the naphtha. When wool has been thus treated by a cleansing agent, dyestuff penetrates better. For some purposes, wool is degreased by extracting the grease with a solvent, such as perchloroethylene. Excess solvent is evaporated off and recovered, and the wool is ready for further processing. This method is used both on stock and piece goods.

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The carding process [illegible] fications of woolen yarns and worsted yarns. Manufacturing processes from this point on depend on whether the wool fiber is to be made into a woolen or worsted product (see Figures 15-4 and 15-5).

In the manufacture of woolen yarns, the essential purpose of carding is to disentangle the fibers by passing the wool fibers between rollers covered with thousands of fine wire teeth. Incidentally, this action also removes some dirt and foreign matter from the fibers. As the wool fibers are brushed and disentangled by these wires, they tend to lie parallel, which would make woolen yarns too smooth. Since woolen yarns should be somewhat rough or fuzzy, it is not desirable to have the fibers too parallel. By use of an oscillating device, one thin film, or sliver, of wool is placed diagonally and overlapping another sliver to give a crisscross effect to the fibers. This permits the fibers to be disentangled and somewhat parallel and at the same time provides a fuzzy surface to the yarn. After this process, the woolen slivers go directly to the spinning operation.

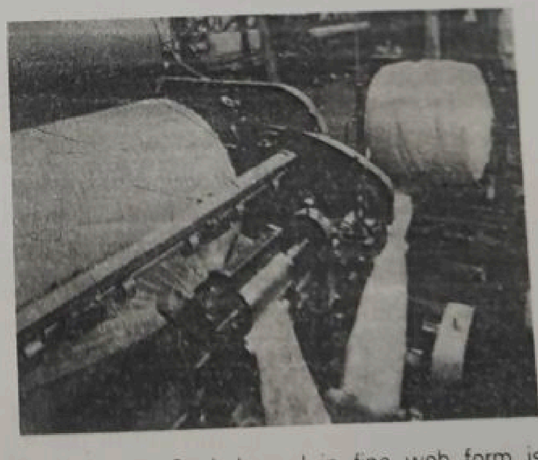


Figure 15-4 Carded wool in fine web form is drawn from the cylinder (left) into woolen sliver (right). *(Courtesy National Association of Wollen Manufacturers)*

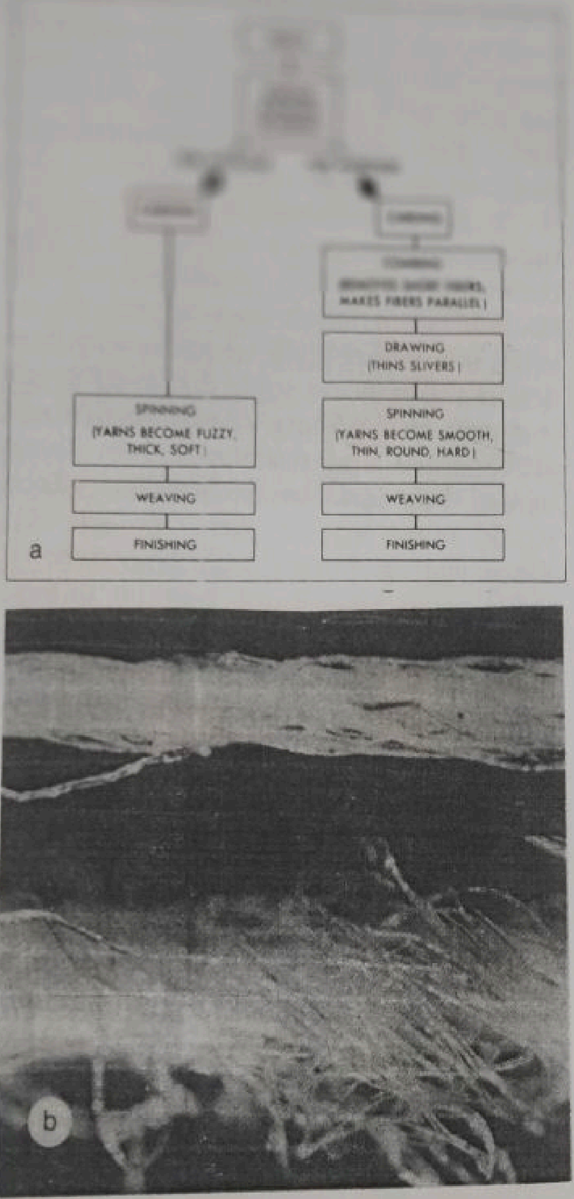


Figure 15-5 (*a*) Diagram shows difference in the manufacture of woolen and worsted yarns. (*b*) Close-up shows that worsted yarn (top) is smoother and more tightly twisted than woolen yard (bottom) which is fuzzy and less tightly twisted. (*Courtesy The Wool Bureau, Inc.*)

When the crimp and loft of the wool fiber is to be increased, as is sometimes desirable particularly for woolen carpet yarns, the carding process may include the use of the IWS Crimper to produce *programmed pile* (see page 61).

In the manufacture of worsted yarns, the essential purpose of carding is also to disentangle the fibers by passing the wool fibers between rollers covered with fine wire teeth. Since worsted yarns, however, should be smooth, the fibers are made to lie as parallel as this process will permit. Following this operation, the wool goes to the gilling and combing processes.

Gilling and Combing

The carded wool, which is to be made into worsted yarn, is put through gilling and combing operations. The *gilling* process removes the shorter staple and straightens the fibers. This process is continued in the *combing* operation, which removes the shorter fibers of 1- to 4-inch (25–100 mm) lengths (called *combing noils*), places the longer fibers (called *tops*) as parallel as possible, and further cleans the fibers by removing any remaining loose impurities.

The short-staple noils are not necessarily of poor quality. Combing noils may well be of good quality, depending on the original source of the wool. They may be used as filler for other types of wool fabrics; however, such fibers must be classified recycled wool.

The long-staple tops, which are over 4 inches (100 mm) in length, excel in color, feel, and strength. They are used in the production of such worsted fabrics as serge, whipcord, gabardine, and covert.

Drawing

Drawing is an advanced operation which doubles and redoubles slivers of wool fibers. The process draws, drafts, twists, and winds the stock, making the slivers more compact and thinning them into slubbers. Drawing is done only to worsted yarns.

Roving

This is the final stage before spinning. Roving is actually a light twisting operation to hold the thin slubbers intact.

Spinning

In the spinning operation, the wool roving is drawn out and twisted into yarn. Woolen yarns are chiefly spun on the mule spinning machine. Worsted yarns are spun on any kind of spinning machine—mule, ring, cap, or flyer. The two principle systems of spinning worsted yarns are the English system and the French system.

In the English system (Bradford), the fiber is oiled before combing, and a tight twist is inserted. This produces smoother and finer yarns. The more tightly twisted yarn makes a stronger, more enduring fabric. In the French system, no oil is used. The yarn is given no twist; it is fuzzier, and therefore suitable for soft worsted yarns.

Wool yarns are also spun on the Selfil system developed in Australia whereby manmade filament fibers are wrapped around a core of wool staple (see pages 44–45).

The differences between woolen and worsted yarns are as follows:

Woolen Yarn	*Worsted Yarn*
Short staple	Long staple
Carded only	Carded and combed
Slack twisted	Tightly twisted
Weaker	Stronger
Bulkier	Finer, smoother, even fibers
Softer	Harder

Yarn Count

The fineness or thickness of wool yarns is based on different systems for woolen and worsted. [illegible] means two-ply yarns of [illegible] singles, twisted together.

In woolens, the size of the yarn is based on two separate systems: the cut and the American run. The latter is more generally used.

The *cut system*, sometimes called the *Philadelphia* because of its use in that area, uses a base of 300 yards to the cut. Thus, 1 pound of woolen fiber drawn out to 300 yards sets a standard for Nac 1.

In the *American run system*, sometimes called the *New England*, 1 pound of woolen yarn yielding 1600 yards is identified as Nar 1. (Also see tex conversion, Table 2-1.)

Warping

The yarn that leaves the spinning frame is not of sufficient length to serve as warp yarn on the loom. It is first wound on bobbins or spools and placed on a large rack or frame called a *creel*. As in the warping operation explained in Chapter 4, the warp yarns on the bobbins or spools are evenly wound on the warp beam. They may be immersed in a solution of starch, gum, or similar compound to make them smooth and strong for weaving. In the production of better-quality wool fabrics, a hard-twisted two-ply yarn is frequently used for the warp yarn, as the plied construction gives greater strength.

Weaving Woolen Fabrics

Basically, the weaving process for wool resembles the process described in Chapter 4. The fuzzy woolen yarns obtained in the carding process are made into woolen

TABLE 15-2 DIFFERENCES BETWEEN WOOLEN AND WORSTED FABRICS

	WOOLEN FABRICS	WORSTED FABRICS
Fiber	Short, curly fibers	Long, straight fibers
Yarn	Carded only; slack twist; weaker yarns	Carded and combed; tight twist; greater tensile strength than woolens; generally yarn-dyed
Weave	Indistinct pattern; usually plain weave, sometimes twill; thread count generally less than worsteds	Distinct pattern; chiefly twill weave, infrequently plain weave; more closely woven than woolens
Finish	Soft finish; fulling, flocking, napping, steaming; since napping can conceal quality of construction, woolens are easily adulterated	Hard finish; singed, steamed; unfinished worsteds are napped; adulteration more difficult as fillers would be easily discernible
Appearance and touch	Soft, fuzzy, thick	Firm, wiry or harsh, smooth or rough
Characteristics	Warmer than worsteds, not so durable; nap acts as a protective agent against shine; soft surface catches and holds dirt; stains easily removed	Wrinkle less than woolens, more durable; hold creases and shape; become shiny with use; feel harsh when next to skin; more resistant to dust
Uses	Generally less expensive than worsteds if poorer yarns are used; desirable for sportswear, jackets, sweaters, skirts, blankets, winter use	Costlier yarns; appropriate for tailored and dressy wear; spring and summer coats and suits, tropical suits; good for business wear
Typical fabrics	Tweed, homespun, flannel, broadcloth, shetland, cassimere	Gabardine, whipcord, serge, worsted cheviot, tropical worsted, Bedford cord

fabrics by using the plain weave, or sometimes the twill. The weave pattern is not always discernible because woolen fabrics often have a napped surface. The thread count of woolens is usually less than that of worsteds because the construction is not so compact.

Woolen fabrics are soft, fuzzy, and thick; they are warmer than worsted, but not as durable. Napping gives woolens a soft surface, which acts as a protection against objectionable luster. But napping can conceal poor construction and the quality of the yarns used; therefore, woolens can be more easily adulterated than worsteds. The napped surface tends to catch and hold dirt, but stains can be easily removed. If poorer yarns have been used in woolens, the fabric is less expensive than worsted. Woolens are desirable for sportswear, jackets, sweaters, skirts, blankets, and similar general use. (See Table 15-2.)

Weaving Worsted Fabrics

The worsted yarns, which have been specially carded and combed, are woven into fine worsted fabrics with distinctive patterns, chiefly by means of the twill weave. The plain weave is infrequently used. The thread count of worsteds is higher than that of woolens because the finer yarn permits closer construction.

Worsted fabrics are firm, smooth or rough, and wiry or harsh. They are more durable than woolens and more resistant to dirt. They wrinkle less and hold creases and shape, but they become shiny with use.

Worsted fabrics are costlier than woolens. They are appropriate for tailored and dressy purposes, for spring and summer coats and suits, and for tropical suits. They are suitable for business wear. (See Table 15-2.)

Inspecting and Correcting Flaws

Prior to various wet- and dry-finishing processes, wool fabrics are *perched*, or examined, for defects, which are marked with chalk. Some flaws are corrected by *burling* with a kind of tweezers (called *burling irons*) to remove loose threads and push knots to the back of the cloth and by *specking* to remove specks, burrs, and other foreign matter. Mending and sewing may be required to correct minor catches and similar defects (Figure 15-6).

FINISHING WOOL FABRICS

Wool fabrics are given a variety of finishes similar to those applied to cotton and linen. But the nature of wool is such that certain other finishing processes are used to obtain a compact, firm body and hand. Let us consider these first.

Fulling

After the weaving process, woolen and worsted gray goods are placed in warm, soapy water and are pounded and twisted to make the wool fibers interlock. This application of heat, moisture, and pressure, followed by a cold rinse, is called fulling (also felting or milling). Soaps, [illegible] soften, and lubricate the fibers so that matting will occur.

Fulling produces a desired shrinkage and gives the fabric additional thickness and a firmer, fuller texture. The longer the fulling operation, the greater the shrinkage, with consequent increase in fabric strength.

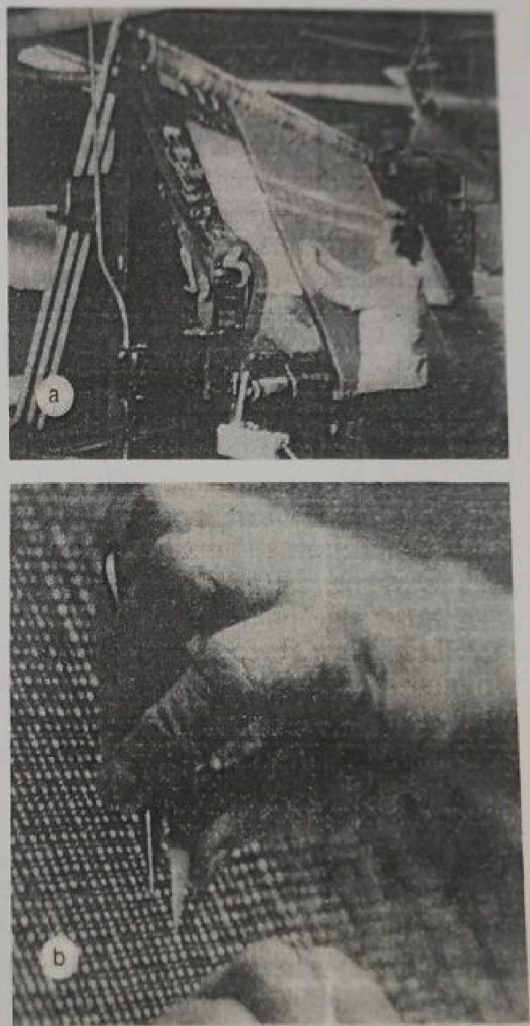


Figure 15-6 (*a*) Fabric inspector on the burling range. (*b*) Closeup of loose threads and knots being removed with burling irons. (*Courtesy Faribault Woolen Mill Co.*)

[illegible] with yarn for low-grade wool fabrics.

Crabbing

To set the cloth and the yarn twist permanently, wool fabric is passed over several cylinders that rotate in hot water and is then immersed quickly in cold water. The cloth is held firmly and tightly to avoid wrinkling. Repetition of the treatment with increased pressure results in setting the cloth and the finish.

Decating

Decating, or decatizing, is a shrinking treatment that is sometimes used instead of London shrinking (see explanation below). Decating, however, is faster and gives reasonable protection against further shrinking. There are two decating techniques, and the one that is used depends upon the luster desired in the finished fabric.

Dry Decating. If the luster is to be set, the fabric is wound under tension on a perforated roller that is then placed in a preheated boiler equipped with a vacuum system. Steam is first forced from the inside of the roller through the layers of fabric for two to three minutes; then the process is reversed. The fabric is then removed and cooled by air.

[illegible] hot [illegible] that is [illegible] fabric [illegible] water [illegible] pro- [illegible] moved, [illegible] air, and [illegible]

London Shrinking

This is a superior preshrinking treatment given to better-quality wool fabrics. It is a cold-water process by which the cloth is interleaved with wet blankets, dried slowly for twenty-four hours, and then set under 3500 pounds of pressure per square inch (24,000 kPa).

Additional Finishing Processes

Wool fabrics are also given the following finishing processes:

Mothproofing—for durability

Napping or gigging—to raise a fuzzy surface

Piece dyeing—to impart color to the wool fabric

Pressing—improving appearance and giving final shape to the cloth

Permanent press—for ease of care and shape retention

Shearing—cutting and shaving for a uniform surface

Shrinkproofing—for stability

Singeing and steaming—for hard finish of worsted fabrics

Steaming, sponging—removing excess glaze

Tentering—for desired uniform width

Water repellency—for all-weather wear

These finishes are fully discussed in Chapters 9 and 10.

UNFINISHED WORSTEDS

Unfinished worsteds have the durability and tailored appearance characteristic of worsted fabrics and the comfort, greater warmth, and freedom from luster characteristic of woolens.

The soft texture of unfinished worsteds is due to additional manufacturing processes, such as fulling, brushing, or napping. Since they require more processing, the term "unfinished" gives a wrong impression.

The napped surface in the unfinished worsted gives softness of texture, serves the functional purposes of napped fabrics, and gives the beauty found in woolens. In addition, the fabric possesses the durability of worsteds. With continued wear, however, the nap rubs off, and these areas show an objectionable luster or shine. Such consumers' goods can be renapped by a cleaning establishment, but this is generally avoided since the renapping can weaken the cloth. One can enjoy longer serviceability by selecting an unfinished worsted in a light color. Light colors, such as gray, do not show luster as readily as the darker shades.

EVALUATING WOOL FABRICS

It is apparent that the quality and characteristics of wool fabrics are dependent upon the kind of sheep, its physical condition, the part of the sheep from which the wool is taken, and the manufacturing and finishing processes applied to the fabrics. While it might appear that these factors present a complicated problem in discerning preferred wool fabrics, there is much information and evidence available to the consumer to help in making satisfactory selections.

While it is not required that the labels on wool fabrics mention the type of sheep wool, fabrics made of Merino wool are frequently identified by label and in advertisements because they are preferred for their softness, warmth, resilience, and fineness. It should be noted, however, that there are trademarks that are similar but not identical in spelling to Merino; such fabrics do not necessarily contain Merino wool.

Another wool fabric that may be readily identified is the Harris Tweed. The wool is obtained from Blackface, the predominant breed, and Cheviot sheep, as well as some crossbreeds which are raised principally for meat on the Outer Hebrides Islands. They produce a quality of wool that is coarse but strong and particularly well suited for durable tweeds. The wool is spun into yarn by machine in mills in Harris and Lewis and then delivered to freelance weavers who comprise the Harris Tweed Association. They weave the fabrics for the mills according to the requested length and pattern on their hand looms in their own sheds adjoining their cottages. The fabrics must be woven of at least 18 warps and 18 wefts per square inch (7.1 threads/cm^2). These tweeds are preferred for their quality of construction, durability, and exclusive designs. These fabrics are identified by the Association's Orb symbol printed every three yards (2.8 m) along the selvage and the registered number of the particular bolt of cloth (Figure 15-7). However, the availability of Harris Tweed has been reduced as the number of members has diminished and those remaining refuse to

Figure 15-7 Genuine Harris Tweed is always identified by a label such as this containing the registered number and the association symbol.

accede to the mills' requests for a change to production on mechanized looms which can produce wider widths at faster speeds, thereby making the fabrics more available for a greater market including such items as upholstery.

Listing the amounts of new and recycled wools is also helpful. The presence of recycled wool in a fabric does not necessarily condemn it so long as the finished product is properly labeled and the consumer understands the limitations as well as the advantages of such wool fabrics. A fabric made of new or virgin wool may be of inferior quality if it is made of inferior grades or of extremely short staple. The yarns should be examined for fineness and crimp of fiber, as these factors have a direct relationship to the quality of wool.

Strength. As wool is the weakest of the natural textile fibers, some wool fabrics may be made more durable by the use of selected grades of recycled wool, although durability is gained at the expense of texture and resiliency. To determine whether temporary body (without strength) has been given by the use of flock, brush and whip the fabric vigorously. Then examine the surface and selvages for powdery particles, which are the sign of short staple. Also examine the structure of the fabric to determine whether it has been weakened by excessive napping.

Wool fabric is strengthened by the use of ply yarns. A hard-twisted two-ply yarn may be regarded as an assurance of durability. Tightly twisted single yarns also make a strong fabric.

Elasticity. One might look upon wool's elasticity as a compensation for its relative weakness. Depending upon the quality of wool, the fiber may be stretched from 25 to 30 percent of its natural length before breaking. This characteristic reduces the danger of tearing under tension and contributes to free body movements. To preserve this natural elasticity, wool garments should be hung properly after wearing and allowed to relax sufficiently to regain their shape (see Figure 15-8).

Wool and wool blend fabrics have been given mechanical (crimp) and chemical (thermofixation) treatments to increase their elasticity and provide better two-way stretch. The chemical treatments have also resulted in improved shape retention.

Resilience. Because wool fiber has a high degree of resilience, wool fabric wrinkles less than some others; wrinkles disappear when the garment or fabric is steamed. Good wool is very soft and resilient; poor wool is harsh. When buying a wool fabric, grasp a handful to determine its quality. If the fabric retains the wrinkles and feels stiff, this may indicate an inferior grade of recycled wool.

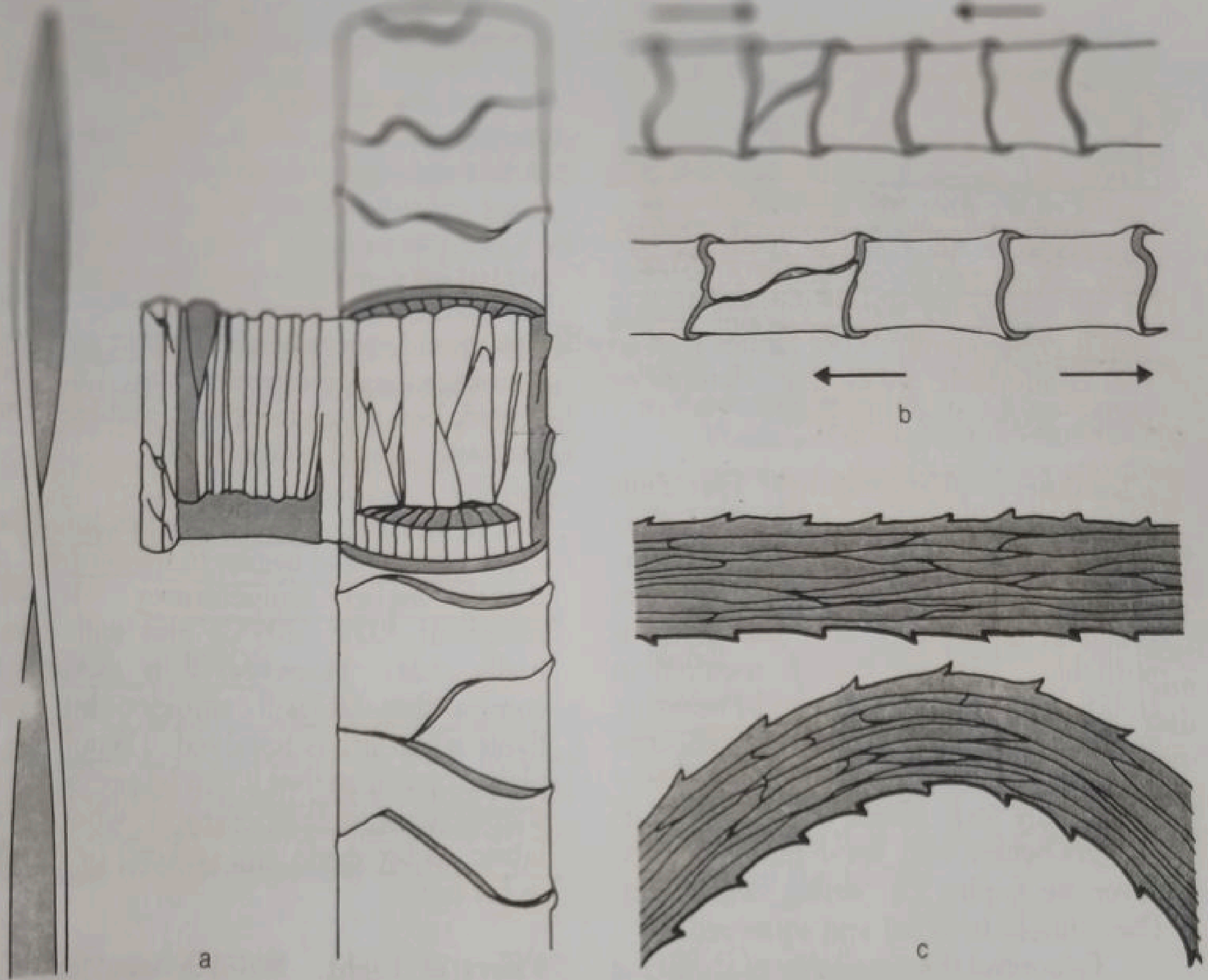


Figure 15-8 (*a*) Model of a magnified wool fiber that has been partially opened to show the inner structure. The epidermal overlapping scales of the fiber cover numerous cortical spindle-shaped cells, a reproduction of which is shown at the left of the fiber model. The fiber's structure provides its elasticity, resilience, warmth, and felting properties. (*b*) Elasticity is facilitated by the surface scales sliding back and forth over each other. The inner cells also slide among each other in a similar manner. (*c*) This diagram of a wool fiber split length-wise depicts how the inner cells slide in and out of position allowing repeated bending without breaking (or creasing), thus providing resilience.

Drapability. Wool's excellent draping quality is aided by its pliability, elasticity, and resiliency. One of the outstanding competitive features that wool has over many manmade fibers is its superior drapability.

Heat Conductivity. As wool fibers are nonconductors of heat, they permit the body to retain its normal temperature. Wool garments are excellent for winter clothing and are protective on damp days throughout the year. The scales on the surface of a fiber and the crimp in the fiber create little pockets of air that serve as insulative barriers and give the garment greater warmth. Low-twist yarns will also contribute to the warmth of the garment. Lightweight wool of sheer construction can be comfortable for summer wear in suitable garment styling because of its thermostatic quality.

[illegible] scales of the fiber, the fiber's high degree of capillarity will result in ready absorption. Wool can absorb about 20 percent of its weight in water without feeling damp; consequently, wool fabrics tend to feel comfortable rather than clammy or chilly. Wool also dries slowly.

Cleanliness and Washability. Dirt tends to adhere to wool fabric. Unless thoroughly cleaned, wool retains odors. Consequently, wool requires frequent dry cleaning, or laundering if the fabric is washable. Extreme care is required in laundering. Wool is softened by moisture and heat, and shrinking and felting occur when the fabric is washed. Since wool temporarily loses about 25 percent of its strength when wet, wool fabrics should never be pulled or wrung while wet. They should be lifted and squeezed.

To control the possibility of shrinking or stretching when laundering a wool sweater or a similar garment, wash it in cold water with an appropriate detergent. To dry the garment, roll it in a towel, squeeze gently to remove as much moisture as possible, then spread it out to its original shape on a towel or heavy cardboard.

Reaction to Bleaches. The household bleaches that contain sodium hypochlorite or other chlorine compounds are harmful to wool. However, a bleach containing hydrogen peroxide or sodium perborate, such as Snowy, may be safely used.

Shrinkage. Shrinkage is greater in woolens than in worsteds, but all fabrics made of wool are subject to shrinkage, de- [illegible] (see Chapter 6). If the fabrics are dry cleaned, the shrinkage will be less. Chlorinated wools are wools that have been subjected to shrinkproofing, but this treatment reduces the strength of the fabric.

If fabrics have been preshrunk or treated for shrinkproofing, this fact should be stated on the identifying labels. These tags should also indicate whether residual shrinkage may be expected, and if it is expected, how much to expect, and how the garments should be cared for.

Effect of Heat. Wool becomes harsh at 212°F (100°C) and begins to decompose at slightly higher temperatures. It will scorch at 400°F (204°C) and will eventually char. However, it is not easily combustible—it will smolder but not flame when fire is removed. Wool has a plastic quality in that it can be pressed and shaped at steam temperatures, whether in fabric, as for slacks and jackets, or in felt, as for hats.

Effect of Light. Wool is weakened by prolonged exposure to sunlight.

Resistance to Mildew. Wool is not ordinarily susceptible to mildew; but if left in a damp condition, mildew develops.

Resistance to Insects. Wool fabrics are especially vulnerable to the larvae of moths and such other insects as carpet beetles. They should be protected in some manner, as discussed in Chapter 10.

Reaction to Alkalies. Wool is quickly damaged by strong alkalies. It is imperative to use a mild soap or detergent when laundering wool fabrics.

Reaction to Acids. Although wool is damaged by hot sulfuric acid, it is not af-

[illegible]

[illegible] Because of their high [illegible], wool fabrics dye well and evenly. The use of chrome dyes assures fastness of color. A variety of other dyes may be effectively used (see Table 11-1).

Resistance to Perspiration. Wool is weakened by alkali perspiration. Garments should be dry cleaned or washed with care to avoid deterioration and odor. Perspiration, generally, will cause discoloration.

WOOL BLENDS

Wool is blended with a wide variety of fibers. The properties of wool blended with cotton and with linen will be considered here; blends with other fibers are discussed in their respective chapters.

Wool and Cotton

Wool is blended with cotton in various ratios. The properties of the yarns and fabrics will be affected by the proportion of the fibers blended. Wool contributes warmth, resilience, abrasion resistance, and drapability. Cotton adds strength and reduces the cost of the yarn and fabric. Both fibers are absorbent and can be blended to make a comfortable, durable fabric with a nice hand.

Wool and Linen

Wool is sometimes blended with linen. Linron may be used (see page 264). Such a blend is stronger and cooler than a pure wool fabric, but is more resilient and drapable than a pure linen fabric.

[illegible]

[illegible] fibers that have qualities of wool are [illegible] from certain kinds of animals throughout the world. The hair of these animals has been so adapted by nature for the climate in which they live that the cloth produced from the fiber gives warmth with light weight. Some of these animals are used primarily as burden carriers; others are bred for their fleeces, which produce the most expensive fibers in the textile industry.

These hair fibers are used alone or are combined with sheep's wool for construction into fabrics whose cost varies according to the amount and quality of the blend. The consumer must be careful to analyze descriptions of certain of these blends. Parts of the names of rare animals are sometimes used to convey false or nonexistent values to mixtures with other fibers. Such blends may contain insignificant quantities of the lowest grade of hair fibers that could not possibly add quality to the fabrics.

CAMEL HAIR

Camel hair is a fine hair that is known to the American consumer chiefly in the form of high-quality coat fabrics. This textile fiber is obtained from the two-humped Bactrian camel, which is native to all parts of Asia (Figure 15-9*a*). The climate of the desert countries, where the camel is used as a burden carrier and as a means of transportation, is exceedingly hot during the day and extremely cold at night. This constant change has produced a protective hair covering that insulates the body in both heat and cold; it is also naturally water-repellent. In the spring, the year's growth of hair, which hangs from the camel in matted strands and tufts, falls off in clumps to make room

Figure 15-9 (*a*) Camels. (*Courtesy American Museum of Natural History*) (*b*) Angora goat. (*Courtesy Arthur Ambler*) (*c*) Llamas. (*Courtesy S. Stroock & Co., Inc.*) (*d*) Alpaca. (*Courtesy New York Zoological Society*) (*e*) Vicuña. (*Courtesy Margot Conte/Animals, Animals*) (*f*) Musk oxen. (*Courtesy Public Archives Canada*)

for the new growth. Masses of hair that are shed throughout the year are also accumulated. The camel is sometimes plucked to obtain the down or underhair.

Camel hair fabrics are ideal for comfort, particularly when used for overcoating, as they are especially warm but light in weight. Camel hair is characterized by strength, luster, and smoothness. The best quality is expensive when used alone. It is often mixed with wool, thus raising the quality of the wool fabric by adding the fine qualities of camel hair. The price of a mixed cloth is naturally much less than that of a fabric that is 100 percent camel hair.

In the textile industry, camel hair is divided into three grades. Grade 1 is the

soft and silky light-tan underhair found close to the skin of the camel. This is short staple, or noil, of from 1¼ to 3½ inches (30–90 mm), but it is also the choicest quality. Formerly, it was the only true camel hair used in the manufacture of apparel. In wool, noils represent the less valuable short staple; in the hair fibers, the short fibers are the prized product and are the only ones used in high-grade hair fabrics.

Grade 2 is the intermediate growth, consisting of short hairs and partly of coarse outer hairs, ranging from 1½ to 5 inches (40–125 mm) in length. Grade 3 consists entirely of coarse outer hairs measuring up to 15 inches (380 mm) in length and varying in color from brownish black [illegible] This grade has no [illegible] manufacture; it is suitable only for cordage and for low-quality rugs.

MOHAIR

Mohair is the hair of the Angora goat, native to the province of Angora, Turkey (Figure 15-9*b*). This species of goat is now raised in South Africa and the United States, principally in Oregon, California, and Texas. Some domestic mohair, particularly the mohair obtained from Texas, is of excellent quality. Imported mohair is long staple, 9 to 12 inches (230–300 mm) long, and represents a full year's growth. The domestic goat is shorn twice a year, yielding a shorter staple, from 8 to 10 inches (200–250 mm). Imported mohair can be spun to a fineness of Ne 60 in yarn count. The highest count possible for domestic fiber is Ne 40. The domestic fiber has a great amount of coarse, stiff hair, known as *kemp*, which does not process readily or allow thorough penetration of dye.

Mohair is a smooth, strong, and resilient fiber. It does not attract or hold dirt particles. It absorbs dye evenly and permanently. Its fine silklike luster permits interesting decorative effects. Mohair fiber is more uniform in diameter than wool fiber. Under the microscope, mohair shows almost no scales; its indistinct scales do not project from the shaft, as is characteristic of wool fiber. Mohair, therefore, does not shrink or felt as readily as wool.

When mohair is used in pile fabrics, the naturally strong fiber combined with the strength of the pile weave makes an especially durable and serviceable fabric. Mohair fabrics are wrinkle-resistant and do not mat readily because of the natural resiliency of the fiber. The fabric can also be made mothproof. Because mohair is very resilient and is stronger than wool or the other hair fibers, it is used to great advantage in better grades of upholstery and drapery materials and in summer suitings. Paradoxically for a hair fiber, mohair fabrics split if pressed sharply and continually, as along a crease.

CASHMERE

The Cashmere goat is native to the Himalaya Mountain region of Kashmir in India, Mongolia, and China. The fleece of this goat has long, straight, coarse outer hair of little value; however, the small quantity of underhair, or down, is made into luxuriously soft woollike yarns with a characteristic highly napped finish. This fine cashmere fiber is not sheared from the goat but is obtained by frequent combings during the shedding season. The microscope reveals that cashmere is a much finer fiber than mohair or any wool fiber obtained from sheep. The scales are less distinct and are farther apart; the fiber appears to be made of sections placed within each other.

Cashmere is used for such garments as sweaters, sports jackets, and overcoats. It is desirable because it is soft, lighter in weight than wool, and quite warm; however, because it is a soft, delicate fiber, fabrics produced from cashmere are not as durable as wool.

LLAMA

The llama is allied to the camel in species, having many of the characteristics of that animal, but being about one-third in size (Figure 15-9c). The llama is the traditional burden carrier in the higher parts of the Andes Mountains in South America, primarily Bolivia and Peru, and has not been bred for its fleece. Its hair fiber is generally coarse and brownish in color and is valued because it may be mixed with the hair of the alpaca, an animal of the same species that is raised for its fleece alone. Some noils are obtained from the undercoat of the llama.

When llama is part of a blend of fibers, it gives exquisite natural colors. Llama mixtures have a characteristic high insulative property with little weight and are used for high-quality coat fabrics, as they embody the essential qualities of wrinkle resistance, color fastness, and extreme durability.

ALPACA

In the higher regions of the Andes, 14,000 feet (4250 m) above sea level, is found another fleece bearer, the alpaca, a domesticated animal that resembles the llama and is related to the camel (Figure 15-9*d*). The fiber is valued for its silky beauty as well as for its strength. The hair of the alpaca is stronger than ordinary sheep's wool, is water-repellent, and has a high insulative quality. The staple is relatively long, ranging from 6 to 11 inches (150–280 mm); yet it is as delicate, soft, and lustrous as the finest silk.

Alpaca consists of two varieties of fiber: soft, wool-like hair, and stiff beard, or outer hair. Of the many colors obtainable, ranging from white to brown and black, the reddish brown variety is considered the most valuable.

A more highly selected type of alpaca is the *suri*—a superbreed just as the Merino is the highest type of sheep. The fiber of the suri is sought by manufacturers of outer apparel because the staple is longer, silkier, and finer, and has curl throughout its length. A crossbreed, with the alpaca as sire and the llama as dam, produces the *misti*. Another crossbreed, the *huarizo*, is the result of breeding a llama sire and an alpaca dam.

VICUÑA

The rare animal whose fiber makes the world's most costly and most exquisite cloth, surpassing all others in fineness and beauty, is found in an almost inaccessible area of the Andes Mountains, at altitudes between 16,000 and 19,000 feet (4875–5800 m). The vicuña, one of the wildest of animals, is less than 3 feet (90 cm) high and weighs 75 to 100 pounds (35–45 kg) (Figure 15-9*e*). A single animal yields only ¼ pound (100 g) of hair; thus forty animals are required to provide enough hair for the average coat. To preserve the species, the vicuña is now under the protection of the Peruvian and Bolivian governments. Attempts to domesticate this animal have not been very successful but are still being made in Peru. The fiber of the vicuña is the softest and most delicate of the known animal fibers; yet it is strong for its weight, is resilient, and has a marked degree of elasticity and surface cohesion. It is the most expensive fiber used in suitings and overcoat fabrics of natural tan to orange-brown.

GUANACO

The guanaco, native to southern Argentina where it is both wild and domesticated, is related to the llama and alpaca. The fiber is extremely soft and silky. It is also light, resilient, and warm, and the color is a honey beige. Because of these characteristics and its limited availability, it is expensive. It generally is blended with wool, frequently lamb's wool, so as not to mask the fiber's soft texture.

ANGORA

The Angora rabbit produces long, fine, silky white hair that is clipped or combed every 3 to 4 months. The finest angora comes from France, Italy, and Japan. The Angora rabbit is also raised in many other parts of the world, including the United States. The fiber's smooth, silky texture makes it difficult to spin, and the fibers tend to slip out of the yarn and shed from the fabric; nevertheless, the fiber is desired for its texture, warmth, light weight, and pure white color, although it is sometimes dyed in pastel shades. Angora rabbit hair is used primarily for items such as sweaters, mittens, baby clothes, and millinery.

QIVIUT

One of the softest hair fibers, which makes very warm yet light fabrics, is the underhair of the musk ox, called *qiviut*. Great interest has been aroused in raising musk ox in Alaska and northern Canada, both for its meat and for the fiber, which is shed in early summer. This fiber can be dyed but is usually used in its natural shades of taupe-gray. Each animal sheds nearly 33 pounds (15 kg) of such lofty fiber that about a half pound (200 g) of it will make a large sweater (see Figure 15-9*f*).

MINOR HAIR FIBERS

There are several hair fibers identified by the FTC that are used for specialized purposes and for a limited extent. These are:

Cow hair obtained from the hides of slaughtered cows. It is used for felts and coarse rugs and cushions.

Horsehair obtained primarily from horses' manes and tails. It is used as a shape retainer in suits and coats and for stuffing in mattresses and upholstery.

Rabbit hair obtained from the common rabbit. It is used for felt in hats.

Down and *feathers* obtained from geese and ducks. They are used for stuffing for pillows, comforters, quilted outerwear, and upholstery.

REVIEW QUESTIONS

1. What are the advantages of wool fabrics?
2. Name the classification of fleeces according to quality.
3. What countries supply the world with wool?
4. Explain the U.S. government classifications of wool.
5. ... found in fleece
7. Name six differences between woolens and worsteds.
8. Name three woolen fabrics and three worsted fabrics.
9. What are unfinished worsteds?
10. How would you judge quality in wool fabrics?
11. What finishing processes are used for woolens?

Chapter 16

SILK

another natural protein fiber

Silk is the very fine strand of fiber that is a solidified *protein* secretion produced by certain caterpillars to encase themselves in the form of cocoons.

HISTORY OF SILK

The possibility of making cloth from the filament that the silkworm spins into a cocoon was first discovered in China about 2600 B.C. Legend tells us that a cocoon accidentally dropped into a cup of tea that a Chinese princess was having in her garden. The hot liquid softened and loosened the fiber, which the princess pulled and drew away from the cocoon as a continuous strand. Another story cites Empress Si-Ling-Chi as the first producer of silk fiber, from which she made a silk robe for her husband. From antiquity until the more recent establishment of the Chinese Republic, she was venerated as the Goddess of the Silkworm.

The Chinese who first cultivated the silkworm and developed a silk industry endeavored to keep the source of the raw material secret. Their silk fabrics were highly prized. Caravans carried silks into the Near East where they were traded for hundreds of years. It is believed that silk was introduced into Europe by Alexander the Great in the fourth century B.C. As the desire for silk fabrics expanded, the interest in its production also increased. About three thousand years after its original discovery, the secret was stolen out of China.

A large silk industry eventually developed in southeastern Europe and subsequently spread westward because of the Moslem conquests. Spain began to produce silk in the eighth century. Italy began silk production in the twelfth century and was the leader for five hundred years. In the sixteenth century, France became the rival of Italy in the production of silk fabrics of excellence and beauty.

Attempts have been made to cultivate the silkworm in the United States, but they have not succeeded commercially because of the higher labor and production costs. The manufacture of silk fabrics is important, however, because silk represents an ideal of luxury. Silk continues to be prized by the consumer even though some manmade fibers now have some qualities that were formerly possessed only by silk.

SILK-PRODUCING COUNTRIES

When farmers in the Asiatic countries first raised silkworms, the many diseased worms and defective cocoons resulted in poor grades of finished goods. The farmers were raising silkworms only as an additional means of support. Japan was the first country producing silk in large quantities to use scientific methods in cultivating the silkworm on farms as well as in factories. Japan has therefore always ranked highest in the production of fine silk, although satisfactory types are made in other silk-producing countries—China, India, Italy, Spain, France, Austria, Iran, Turkey, Greece, Syria, Bulgaria, and Brazil. The cultivation of the silkworm requires extreme care and close supervision, and the reeling of the filament from the cocoons can be undertaken only by skilled operators.

CULTIVATION OF COCOONS

Since the discovery, so many years ago, that the fiber, or filament, composing the cocoon of the silkworm can be unwound and constructed into a beautiful and durable fabric, silkworms have been bred for the sole purpose of producing raw silk. The production of cocoons for their filament is called *sericulture*. Experiments have proved that the cocoon of the *Bombyx mori*, a species of moth, produces the finest quality of raw silk. In sericulture, all four stages of the life cycle of this moth are important, because some of the better cocoons must be set aside to permit full development, thus supplying eggs for another hatching. Under scientific breeding, silkworms may be hatched three times a year; under natural conditions, breeding occurs only once a year. The life cycle is as follows (see also Figure 16-1):

1. The egg, which develops into the larva, or caterpillar—the silkworm
2. The silkworm, which spins its cocoon for protection, to permit development into the pupa, or chrysalis
3. The chrysalis, which emerges from the cocoon as the moth
4. The moth, of which the female lays eggs, so continuing the life cycle

Within three days after emerging from the cocoons, the moths mate, the female lays 350 to 400 eggs on numbered cards, and the moths die. Based upon Louis Pasteur's discovery that the insect is subject to a hereditary infection, the moths are then examined microscopically. The cards of eggs from moths that have been infected are burned. By this careful, scientific regulation, Japan has not only protected and fostered sericulture but has developed into the leading producer of silk fiber.

Each healthy egg hatches into what is called an *ant*. It is a larva about ⅛ inch (3 mm) in length. The larva requires careful nurturing in a controlled atmosphere for approximately twenty to thirty-two days. During this period, the tiny worm has a voracious appetite. It is fed 5 times a day on chopped mulberry leaves (see Figure 16-2). After four changes of skin, or moltings, the worm reaches full growth in the form of a smooth grayish-white caterpillar about 3½ inches (9 cm) long. Its interest in food ceases. It

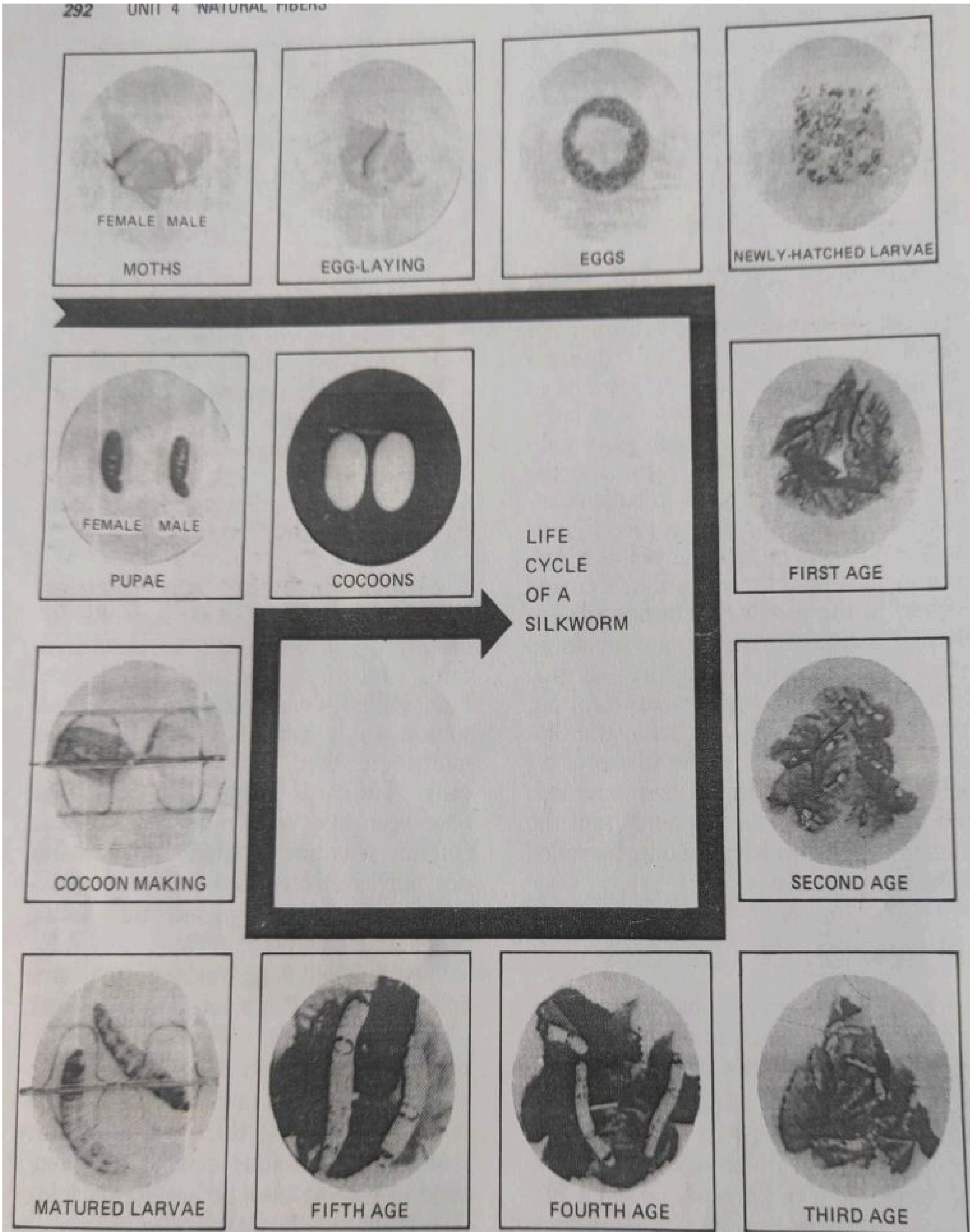


Figure 16-1 Nature's production of silk fiber.

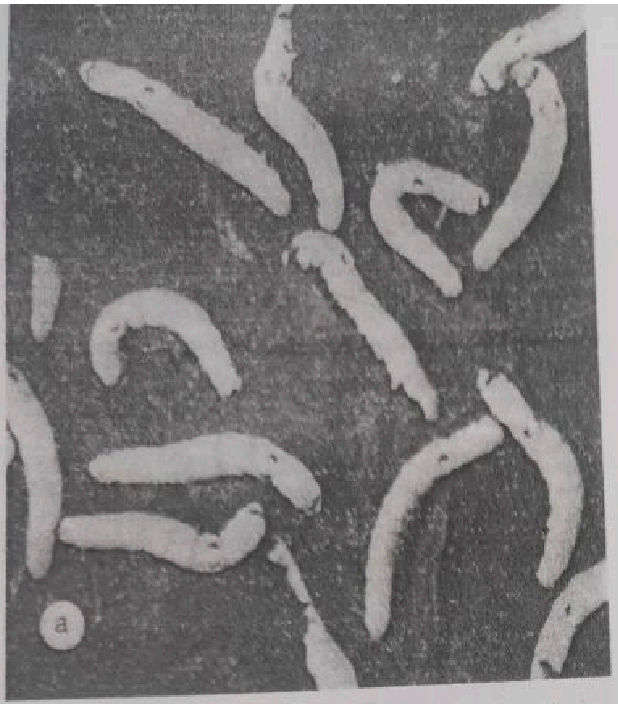


Figure 16-2 (*a*) Silkworms feeding on mulberry leaves. (*b*) Close-up of silkworm eating a mulberry leaf. (*Courtesy The Japan Silk Association, Inc.*)

shrinks somewhat in size and acquires a pinkish hue, becoming nearly transparent. A constant restless rearing movement of the head indicates that the worm is ready to spin its cocoon. Racks, clusters of twigs, or straw are provided for this purpose (see Figure 16-3).

Of importance to the silk industry is the small opening under the caterpillar's jaws, called the *spinneret*. The silkworm begins to secrete a proteinlike substance through its spinneret, and with a bending motion, the filament is spun around the worm in the form of the figure eight (see Figure 16-4). The silkworm is hidden from view within twenty-four hours; in three days, the cocoon is completed. It is about the size and shape of a peanut shell. The filament is in the form of a double strand of *fibroin*, which is held together by a gummy substance called *sericin*, or *silk gum*. The liquid substance hardens immediately on exposure to the air. If left undisturbed, the chrysalis inside the cocoon develops into a moth within two weeks. To emerge, the moth must break through the top of the cocoon by secreting an alkaline liquid that dissolves the filament. As this cutting through damages the cocoon so that the filament cannot be unwound in one long thread, the life cycle is terminated at this point by a process known as *stoving*, or *stifling*. The cocoons are heated to suffocate the chrysalis, but the delicate silk filament is not harmed (see Figure 16-5).

FILATURE OPERATIONS

The cocoons that are raised by silk farmers are delivered to a factory, called a *filature*, where the silk is unwound from the

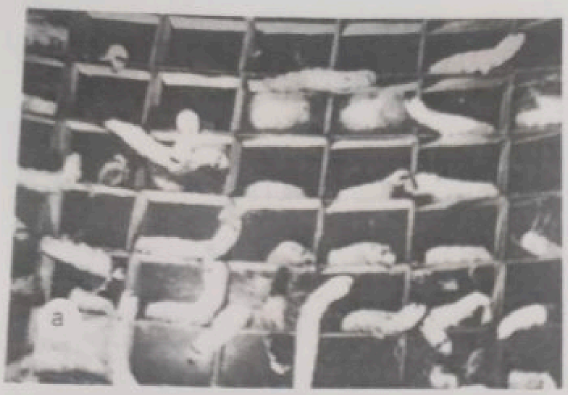


Figure 16-3 (a) Silkworms on a cocooning apparatus. (b) Cocoons on cocooning apparatus. (Courtesy The Japan Silk Association, Inc.)

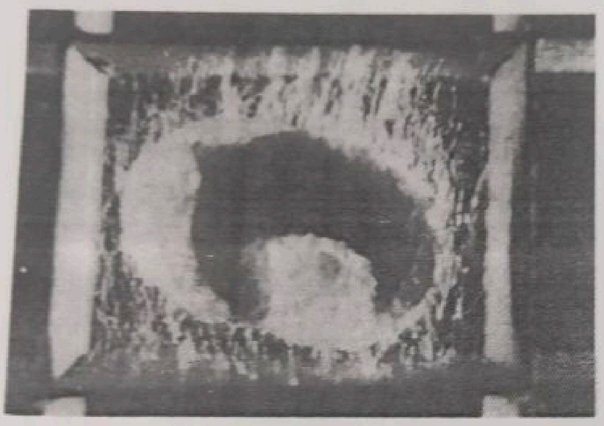


Figure 16-4 Close-up of silkworm spinning the cocoon around itself. (Courtesy The Japan Silk Association, Inc.)

cocoons and the strands are collected into skeins. Some cocoons are scientifically bred in such factories.

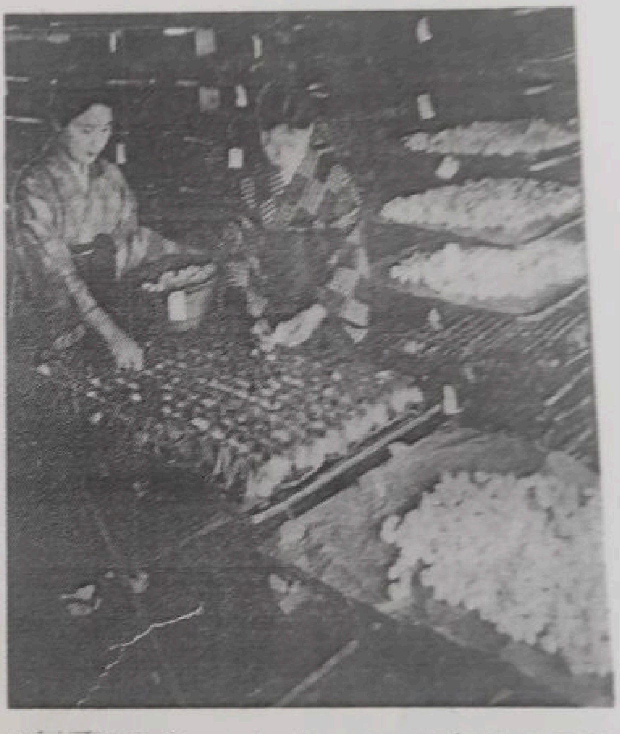


Figure 16-5 Removing the cocoons from nests in preparation for stoving. (Courtesy International Silk Guild)

Sorting Cocoons

The cocoons are sorted according to color, size, shape, and texture, as all these affect the final quality of the silk (Figure 16-6). Cocoons may range from white or yellow to grayish, depending on the source and the type of food consumed during the worm stage. Cocoons from China are white; Japanese cocoons are creamy white and yellow; Italian cocoons are yellow.

Softening the Sericin

After the cocoons have been sorted, they are put through a series of hot and cold immersions, as the sericin must be softened to permit the unwinding of the filament as one continuous thread. Raw silk consists of about 80 percent fibroin and 20 percent sericin. At this time, only about

Figure 16-6 Sorting cocoons. *(Courtesy International Silk Association, Inc.)*

1 percent of the sericin is removed, because this silk gum is a needed protection during the further handling of the delicate filament.

Reeling the Filament

The process of unwinding the filament from the cocoon is called *reeling*. The care and skill used in the reeling operation prevent defects in the raw silk. As the filament of a single cocoon is too fine for commercial use, three to ten strands are usually reeled at a time to produce the desired diameter of raw silk thread. The cocoons float in water, bobbing up and down, as the filaments are drawn upward through porcelain eyelets and are rapidly wound on wheels or drums while the operator watches to detect flaws. As the reeling of the filament from each cocoon nears completion, operators attach a new filament to the moving thread. Skilled operators have an uncanny ability to blend the filaments, while always retaining the same diameter of the rapidly moving silk strand. The sericin acts as an adhesive. It aids in holding the several filaments together while they are combined to form the single thread. On old-style reeling machines at high speed, an operator could handle five to seven threads, and on the newest models, twenty-five threads.

The usable length of the reeled filament is from 1000 to 2000 feet (300–600 m), approximately a quarter of a mile long. The remaining part of the filament is used as valuable raw material for the manufacture of spun silk.

The term "reeled silk" is applied to the raw silk strand that is formed by combining several filaments from separate cocoons. The diameter of the silk fiber is so fine that an estimated 3000 cocoons are required to make a yard (1 m) of silk fabric. The silk filaments are reeled into skeins, which are packed in small bundles called *books*, weighing 5 to 10 pounds (2.0–4.5 kg). These books are put into bales, weighing about 133.33 pounds (60 kg). In this form, the raw silk is shipped to all parts of the world (see Figure 16-7).

MANUFACTURE OF SILK YARNS

From the filature, the books of reeled silk are put through the following manufacturing processes.

Thrown Silk

Reeled silk is transformed into silk yarn—also called silk thread—by a process known as *throwing*. The term is derived from the Anglo-Saxon word "thrawn," meaning "to twist." Persons engaged in this work are called *throwsters*. Silk throwing is analogous to the spinning process that manufactures cotton, linen, or wool fibers into yarn. Unlike those fibers, the manufacture of silk yarn does not include the processes for producing a continuous yarn by carding, combing, and

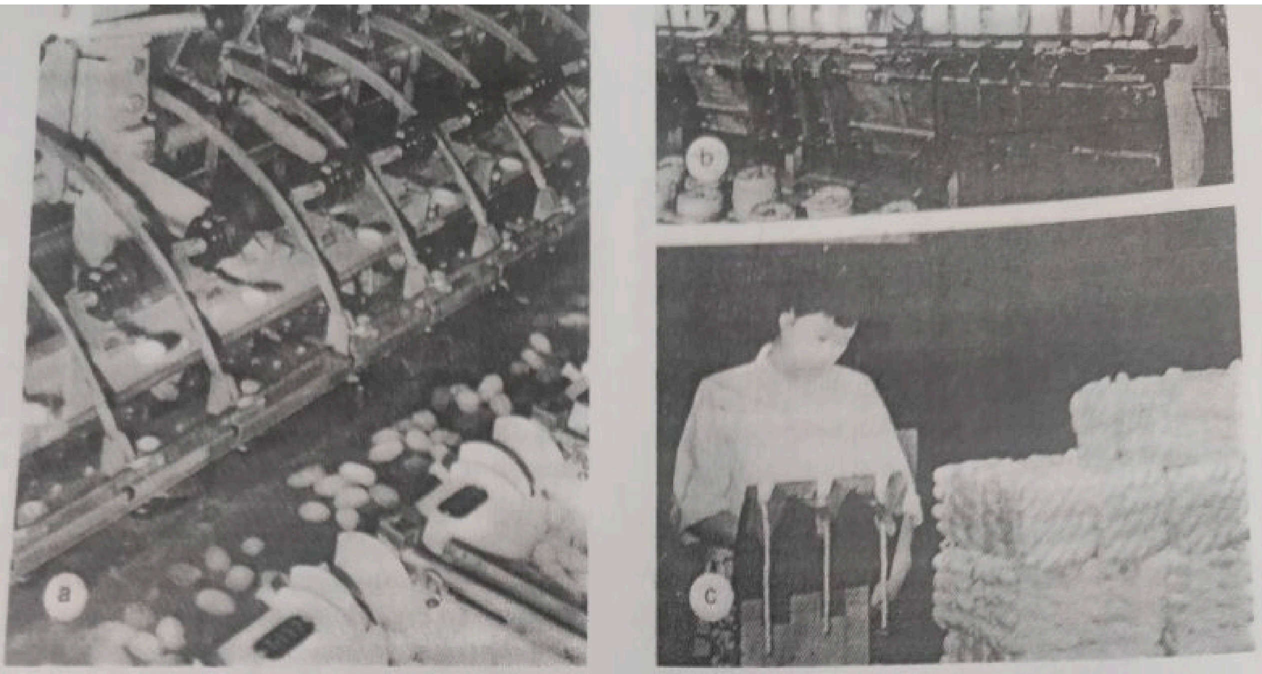


Figure 16-7 (a) Reeling silk cocoons. *(Courtesy The Japan Silk Association, Inc.)* (b) Skeins of reeled silk. (c) Books of reeled silk. *(Photos Courtesy The Central Raw Silk Association of Japan)*

drawing out. The raw silk skeins are sorted according to size, color, and length or quantity, then soaked in warm water with soap or oil. This softening of the sericin aids in handling the thread. After mechanical drying, the skeins are placed on light reels from which the silk is wound on bobbins.

During this winding operation, single strands may be given any desired amount of twist. If two or more yarns are to be doubled, they are twisted again in the same direction or in a reverse direction, depending on the kind of thread to be made. To equalize the diameter, the yarn is run through rollers. The thread is then inspected and packaged and is ready for shipment to manufacturers for construction into fabric.

Kinds of Thrown Silk Yarns. Several kinds of silk yarns, or threads, are used in the manufacture of silk goods. The type of yarn and the amount of twist depend on what the weaver desires.

Singles. Usually, three to eight strands of silk filaments are twisted together in one direction to form a yarn called *a single*. Loose-twist singles, having two or three twists per inch (about 1 twist/cm), are used primarily for the filling yarns in many silk fabrics. Hard-twist singles, having a much greater number of twists per inch, are used in the sheer fabrics (see Figure 16-8*a*).

Tram. Tram is used only as a filling yarn. Usually, two to four untwisted singles are combined with only a slight twist of about three to five turns per inch (1–2/cm). The number of turns may be increased for especially heavy silk fabrics. Tram is rarely twisted more than five turns to the inch (2/cm), except in such fabrics as radium and taffeta, which use a special hard-twisted tram of about thirty turns per inch (12/cm) (see Figure 16-8*b*).

Voile. This yarn is used for such sheer crepes as voile. It is composed of three untwisted singles combined with thirty-five to forty S turns per inch (14–16/cm) (see Figure 16-8*c*).

Georgette or Crepe de Chine. This yarn is composed of two untwisted singles combined with a very hard S or Z twist of seventy to seventy-five turns per inch (28–30/cm). The result is a very fine, strong, elastic yarn used for warp yarns and for such sheer fabrics as georgette or crepe de chine (see Figure 16-8*d*).

Organzine. Organzine is used primarily for warp yarns. It is composed of two or more singles, each of which has sixteen Z turns per inch (6/cm). These singles are then combined by twisting them around each other in the opposite S twist, twelve to twenty turns per inch (5–8/cm), which causes them to interlock more tightly, resulting in a firmer, stronger yarn (see Figure 16-8*e*).

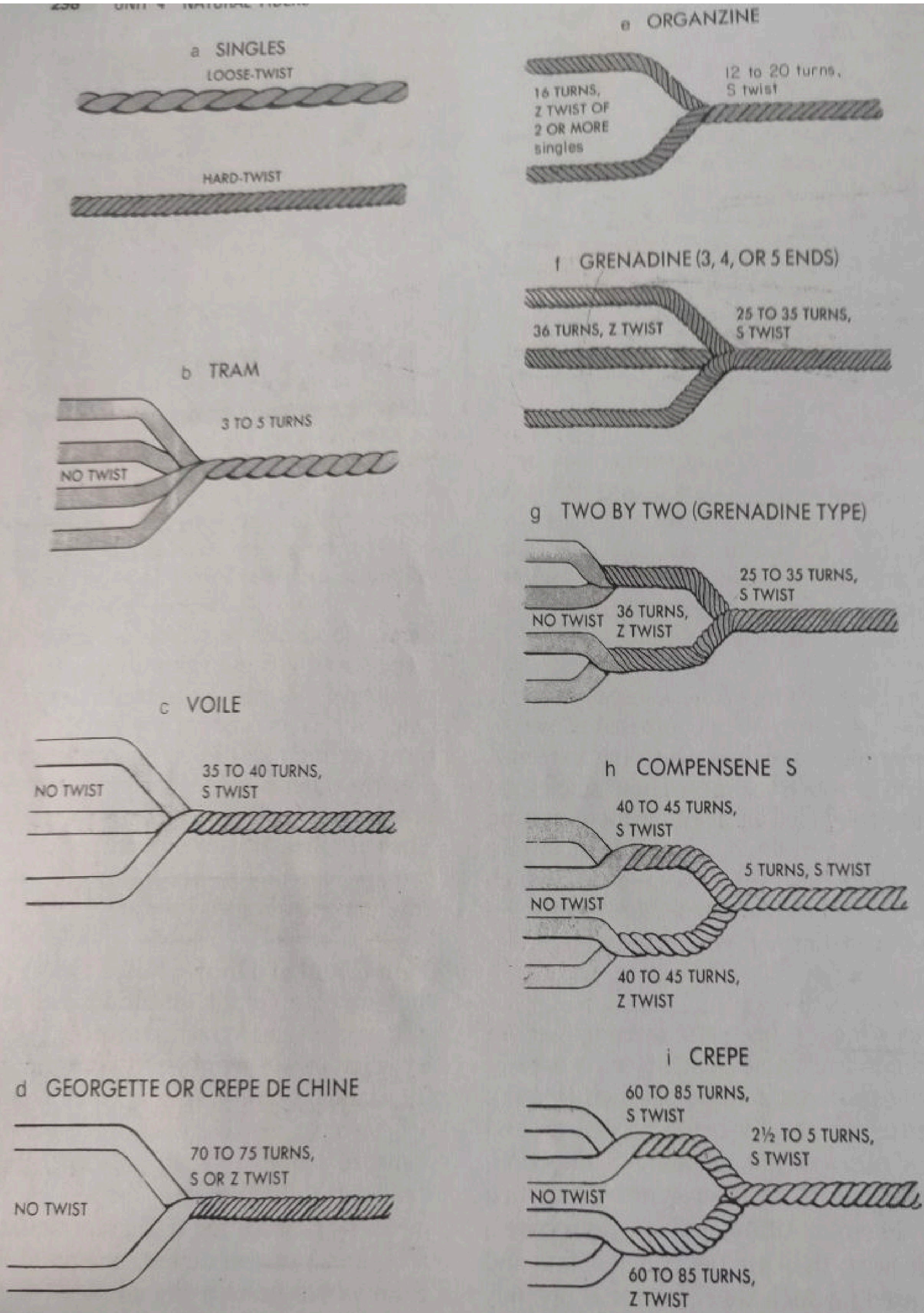
Grenadine. This yarn is composed of three to five singles, each given a twist of about thirty-six Z turns per inch (14/cm), then combined by being twisted around each other in the opposite S direction, twenty-five to thirty-five turns per inch (10–14/cm). Although these yarns have a high twist, they are nevertheless fine and are used for such sheer fabrics as organdy and grenadine (see Figure 16-8*f*).

Two by Two (Grenadine Type). Each of two pairs of untwisted singles is twisted about thirty-six Z turns per inch (14/cm), then twisted around the other twenty-five to thirty-five turns (10–14/cm) in the S direction. These yarns are consequently much like the grenadine yarns but are heavier. Their weight, body, and high twist make them desirable for crepe fabrics (see Figure 16-8*g*).

Compensene S. This yarn is made of each of two pairs of untwisted singles. One pair is twisted together forty to forty-five S turns per inch (16–18/cm); the other is twisted the same number of Z turns per inch (cm). These twisted pairs are then twisted around each other five S turns per inch (2/cm). The opposing directions of these twists prevent kinking but give elasticity. These yarns are often used for knitted fabrics (see Figure 16-8*h*).

Crepe. Some crepe fabrics are made of crepe yarns. These yarns are composed of each of two pairs of untwisted singles. One pair is twisted sixty to eighty-five turns per inch (24–34/cm) in the S direction; the other is twisted the same number of turns per inch (cm) in the Z direction. They are then twisted around each other two and one-half to five S turns per inch (1–2/cm) (see Figure 16-8*i*).

Yarn Count of Thrown Silk. The size or the yarn count of silk threads is based on a system of weight known as *denier*. A denier represents a weight of 0.05 gram and the standard length of a raw silk skein is 450 meters. An increase in weight of a standard length indicates an increase in diameter and, therefore, denier. A 450-meter skein weighing 0.05 gram would be of a thread of one denier, a skein of 0.50 gram would be of a thread of 10 denier, and so forth. Another way of expressing



gure 16-8 Types of thrown silk yarns. "Turns" means turns per inch.

the weight is in grams per 9000 meters. And since the tex system measures in grams per 1000 meters and decitex (dtex) in grams per 10,000 meters, conversion from denier to decitex can be done by multiplying the denier by a factor of 1.111.

The most common size of raw silk from Japan is 14 denier, which is expressed as 13/15 denier (14 to 17 dtex) to allow for variation in the diameter of the yarn. It is as fine as a 350s (1.7 tex) cotton yarn. In the spring crop, four to five cocoons are required to produce such a yarn, whereas the summer and autumn crops require five to six cocoons. As each cocoon is comprised of two filaments, this represents eight to ten or ten to twelve filaments, depending on the season. The greater the number of cocoons used, the thicker the yarn and the higher the denier (dtex).

Degumming of Thrown Silk. Thrown silk yarns still contain some sericin that must be removed in another soap bath to bring out the natural luster and the soft feel of the silk. As much as 25 percent of the weight is lost by the degumming process. When the gum has been removed, the silk fiber or fabric is a creamy white color, beautifully lustrous, and luxuriantly soft.

Degumming may take place after the silk yarn is thrown in order to prepare it for yarn dyeing, or it may be done in any finishing process after the fabric is woven. For example, the tightly twisted yarns used for crepe effects still contain sericin. A small amount of sericin is sometimes left in the yarn or in the fabric to give the finished product added strength or a dull finish. Ecru and souple are examples of silk fabrics from which sericin has been partially removed.

Spun Silk

Short lengths of inferior silk filaments obtained from waste material are not used in producing reeled silk. After the short lengths have been carded and combed, they are spun together much as cotton, linen, or wool yarns are spun. Spun silk yarns are soft, but they are less lustrous than reeled silk and are not as strong or elastic. Spun silk fabric tends to become fuzzy after wearing because the yarn is made of short staple.

There are several sources of staple silk: (1) pierced cocoons, the result of breeding moths that have emerged from their cocoons; (2) double cocoons, the result of two cocoons having been spun by two silkworms too close together (sometimes called *douppioni silk*); (3) floss, brushed from cocoons before reeling; (4) frison, the coarse and uneven silk fiber at the beginning and end of each cocoon; (5) scrap, the machine waste left from reeling, throwing, and the like.

Spun silk is less expensive than reeled silk. Although spun silk has less strength and elasticity because of the shorter staple used, it possesses all the general characteristics of reeled silk. Spun silk is used for shantung and pile fabrics; for dress trimmings, linings, elastic webbing, and sewing silk; for wash silks, velvets, umbrella fabrics, and insulative materials.

The waste derived from the processing of spun silk yarn is also used. The Trade Practice Rules of the FTC require that such fiber be labeled as *waste silk*, *silk waste*, *noil silk*, or *silk noil*. For obvious reasons, the last two designations are most frequently used. Silk noil may be reprocessed into spun yarn and woven into textured fabrics for draperies, upholstery, and sportswear. These fabrics are dull, rough, have a cottonlike appearance, but are generally more resilient.

Yarn Count of Spun Silk. The method of determining the size of spun silk yarn is similar to that used for cotton yarn. In cotton, the term "60/2s" signifies a two-ply yarn consisting of two single strands twisted together, each having a yarn count of 60 (9.8 tex), resulting in the equivalent thickness of a 30s (19.7 tex).

In spun silk, a two-ply yarn is indicated by the figures "60s/2." Although this term appears to be the same as the cotton term, it does not mean the same. In spun silk, 60s/2 means that two yarns, each of a yarn count of 120 (4.9 tex), have been twisted together to produce a ply yarn that has a count of 60 (9.8 tex).

FINISHING SILK FABRICS

As with other textiles, silk fabrics may be given a variety of finishes. There is one finish, though, that is unique to silk. It is weighting.

Weighting

The amount of weight that silk loses in the degumming process is an appreciable factor in manufacturing costs because the manufacturer buys silk by weight. As is customary in any business, the price of the finished product must offset this loss; therefore, silk has always been an expensive fabric. The weighting of silk fabric with metallic substances to make up for the weight lost by degumming is an accepted practice in the silk industry. This procedure lowers the cost of silk to the consumer.

Weighted silk is less compactly woven than unweighted silk and less silk is used in the construction of the cloth. In other words, weighting rather than compact construction can give firmness and body to a silk fabric. Weighting is done during the dyeing process. To weight colored silks, stannic chloride is used, followed by treatment with sodium phosphate. Black silks are weighted with metallic mordants, such as iron salt and logwood.

A small amount of metallic weighting, correctly applied to a fabric that is well woven to hold the weighting, is not considered injurious. In addition to lowering the cost, it is claimed that weighting gives silk crispness, luster, and firmer body and feel. When weighted silk is pleated, the crease is retained. Weighted silk, however, loses the natural elasticity of the silk fiber and is subject to deterioration when exposed to sunlight, perspiration, and dry cleaning. When the fabric is not properly constructed, threads shift. If the fabric is not woven sufficiently wide to allow for natural shrinkage, there is an unsatisfactory amount of shrinkage.

Taffeta is a commonly used fabric that is usually heavily weighted, because today there is little demand for pure-dye taffeta. Weighted taffeta is apt to crack and split at the places subjected to the strain of wear and folded for a length of time. (Rayon and acetate taffeta do not contain any metallic weighting.) Because the consumer cannot determine the percentage of weighting in a silk fabric, the FTC ruled in 1938 that weighted silk must be labeled, and the percentage of weighting must be indicated.

Pure-Dye Silk

As silk is weighted during the dyeing process, the term "pure-dye silk" indicates that weighting was not added at that time. According to the FTC rulings, pure-dye silk is defined as a fabric made exclusively of silk fibers containing "no metallic weighting whatsoever." But the use of such water-soluble substances as starch, glue, sugar, or gelatin in the dyeing and finishing processes is allowed. Such foreign substances are limited to 10 percent for white or colored silks and 15 percent for black silks. Well-constructed pure-dye silk requires a greater amount of silk thread than weighted silk because pure-dye silk is usually more compact. Thus it is generally superior, having the qualities of elasticity and durability, because the natural elasticity of the silk fiber has not been lessened, and its great natural strength has been retained.

Additional Finishing Processes

A variety of other finishes may be applied to silk fabrics to enhance their appearance, hand, or serviceability. The major finishes are as follows:

Bleaching—very little is required for silk that is completely degummed

Calendering—for enhancing luster

Ciréing—for body and luster

Embossing—if such patterns as moiré are desired

Pressing and lustering—for removing wrinkles from finished fabric with heated rollers, then soaking in dilute acid to develop luster

Singeing—for smoothness

Steaming—for raising pile weaves

Stiffening—for body

Water repellency—for use as rainwear

Wringing and stretching—for softening the fiber and increasing the luster

For more detailed information on finishing processes the reader is referred to Chapters 9 and 10.

WILD SILK

The silkworms that hatch from a wild species of moth, the *Antheraea mylitta*, live on oak leaves instead of mulberry leaves that form the food of the cultivated species. This coarser food produces an irregular and coarse filament that is hard to bleach and hard to dye. The tannin in the oak leaves gives wild silk its tan color, and the silk is commonly woven with the naturally colored thread; it is rarely dyed except in solid shades. Wild silk is less lustrous than cultivated silk, as only a low percentage (about 11 percent) of sericin is removed in the degumming process. Wild silk fabrics are durable and have a coarse, irregular surface. They are washable and are generally less expensive than pure-dye silk. Typical fabrics are *rajah*, *shantung*, *tussah*, and *pongee*.

The standard wild silk yarn differs from the standard reeled silk yarn in size, as it is made from eighteen cocoons. It averages 32/34 denier (36 to 38 dtex).

EVALUATING SILK FABRICS

In spite of its high cost, silk has been one of the most popular fabrics because of its unique properties. Soft, supple, strong, and lighter in weight than any other natural fiber, silk is prized for its lightness with warmth, sheerness with strength, and delicacy with resiliency.

Strength. Silk is the strongest natural fiber. The continuous length of the filaments in thrown yarns provides a factor of strength above what is possible with short natural fibers. The smoothness of the silk filament yarns reduces the problem of wear from abrasion. The inherent strength of silk along with its fine diameter and lightness has made it a highly desirable fiber for sheer yet durable fabrics. The strength of silk fabric is also affected, of course, by its construction as well as its finish.

Spun silk yarn, though strong, is weaker than thrown silk filament yarns. The quality of spun silk depends upon the source of the staple. Douppioni and pierced-cocoon silk are generally stronger than the other silk staple, which tend to be less uniform.

Elasticity. While silk is an elastic fiber, its elasticity varies, as may be expected of a natural fiber. Silk fiber may be stretched from $^{1}/_{7}$ to $^{1}/_{5}$ its original length before breaking. It returns to its original size gradually and loses little of its elasticity. This characteristic means less binding and sagging, thus contributing to the wearer's comfort. It should be kept in mind that the elasticity of the yarn and the fabric is affected by the kind of yarn used (thrown or spun), the construction of the fabric, and the finish that it is given.

Resilience. Silk fabrics retain their shape and resist wrinkling rather well. This is particularly true of the fabrics made from pure-dye silk and from wild silk. Fabrics that contain a large percentage of weighting or are made from short-staple spun silk have less resilience.

Drapability. Silk has a pliability and suppleness that, aided by its elasticity and resilience, give it excellent drapability.

Heat Conductivity. Like wool, silk is a protein fiber; therefore, it is also a nonconductor of heat. Because silk prevents body heat from radiating outward, it is desirable for winter apparel, including scarves. Thin silk fabrics are also comfortably warm when used for lingerie, pajamas, robes, and linings. The warmth-giving quality is lessened by weighting because the metallic content causes the fabric to become a conductor of heat.

A question often raised is why silk is used for summer fabrics when it is a nonconductor of heat. The answer is that silk, being fine and strong, may be made into very fine yarns and woven into very sheer fabrics. This permits the body heat and the air to pass freely through the open construction of such cloth.

Absorbency. The good absorptive property of silk also contributes to its comfort in a warmer atmosphere. Silk fiber can generally absorb about 11 percent of its weight in moisture, but the range varies from 10 percent to as much as 30 percent. This property is also a major factor in silk's ability to be printed and dyed easily.

Cleanliness and Washability. Silk is a hygienic material because its smooth surface does not attract dirt. When dirt does gather, it is given up readily by washing or dry cleaning. Care should be exercised in laundering silk—always use a mild soap. Wringing or strong agitation in the washing machine should be avoided, as silk weakens slightly when wet.

All silks water-spot easily, but subsequent washing or dry cleaning will restore the appearance of the fabric, unless it has a special finish. Taffeta, for example, may be given a finish that could be permanently stained by water. Dry cleaning is preferable for weighted silks, but wild-silk and spun-silk fabrics may be washed.

Reaction to Bleaches. Strong bleaches containing sodium hypochlorite will deteriorate silk. A mild bleach of hydrogen peroxide or sodium perborate may be used with normal caution.

Shrinkage. Because of the straightness of the filament, smooth-surfaced silk fabrics have only a normal shrinkage, which is easily restored by ironing. Crepe effects shrink considerably in washing, but careful ironing with a moderately hot iron will restore the fabric to its original size.

Effect of Heat. Silk is somewhat sensitive to heat. It will begin to decompose at 330°F (165°C); therefore, it should be ironed while damp with a warm iron.

Effect of Light. Continuous exposure to light weakens silk faster than either cotton or wool. Raw silk is more resistant to light than degummed silk, and weighted silk has the least light resistance. Silk drapery and upholstery fabrics should be protected from direct exposure to the light.

Resistance to Mildew. Silk will not mildew unless left for some time in a damp state or under the extreme conditions of tropical dampness.

Resistance to Insects. Silk may be attacked by the larvae of clothes moths or carpet beetles, and it may be destroyed when blended with wool which is attacked by these insects.

Reaction to Alkalies. Silk is not as sensitive as wool is to alkalies, but it can be damaged if the concentration and the temperature are high enough. Use a mild soap or detergent in lukewarm water when laundering.

Reaction to Acids. Concentrated mineral acids will dissolve silk faster than wool. Organic acids do not harm silk.

Affinity for Dyes. Silk has a very good affinity for dyes. It readily absorbs basic, acid, and direct dyes. Prints on silk are taken so well that the color on the back of the fabric often differs only slightly from the face.

Dyed silk is colorfast under most conditions, but its resistance to light is unsatisfactory. The resistance of weighted silk is particularly poor; therefore, silk is not recommended for window curtains. Pure-dye silks may be redyed by the consumer, provided a suitable commercial dye is used and the directions on the container are followed.

Resistance to Perspiration. Silk fabrics are damaged by perspiration. The silk itself deteriorates, and the color is affected, causing staining. Garments worn next to the skin should be washed or otherwise cleaned after each wearing.

SILK BLENDS

Silk is blended with many fibers. When it is to be blended with any of the natural fibers, silk noil is used. This makes blending and spinning possible because all of the fibers are of staple length. The resultant properties depend upon the ratio of the fibers blended.

Silk and Cotton

When silk is blended with cotton, silk contributes a soft, smooth hand, lightness of weight with strength, resilience, comfort, and good color possibilities. Cotton provides body and lower cost.

remove the naphtha. When wool has been thus treated by a cleansing agent, dyestuff penetrates better. For some purposes, wool is degreased by extracting the grease with a solvent, such as perchloroethylene. Excess solvent is evaporated off and recovered, and the wool is ready for further processing. This method is used both on stock and piece goods.

Drying. Wool is not allowed to become absolutely dry. Usually, about 12 to 16 percent of the moisture is left in the wool to condition it for subsequent handling.

Oiling. As wool is unmanageable after scouring, the fiber is usually treated with various oils, including animal, vegetable, and mineral, or a blend of these to keep it from becoming brittle and to lubricate it for the spinning operation.

Dyeing

If the wool is to be dyed in the raw stock, it is dyed at this stage. The advantage of stock dyeing has been described in Chapter 11. Some wool fabrics are piece-dyed, some are yarn- or skein-dyed, and some are top-dyed.

Blending

Wool of different grades may be blended or mixed together at this point. It is not uncommon for taglocks and inferior grades of wool to be mixed with the better grades. The use of a mixture with a coarser grade of fiber is a legitimate practice if the purpose is to make a hardier product and a less expensive one, provided the label on the finished goods indicates a true description of the raw materials used. Subsequent to wool grade blending, other fibers may be blended with the wool (see page 283).

Carding

The carding process introduces the classifications of woolen yarns and worsted yarns. Manufacturing processes from this point on depend on whether the wool fiber is to be made into a woolen or worsted product (see Figures 15-4 and 15-5).

In the manufacture of woolen yarns, the essential purpose of carding is to disentangle the fibers by passing the wool fibers between rollers covered with thousands of fine wire teeth. Incidentally, this action also removes some dirt and foreign matter from the fibers. As the wool fibers are brushed and disentangled by these wires, they tend to lie parallel, which would make woolen yarns too smooth. Since woolen yarns should be somewhat rough or fuzzy, it is not desirable to have the fibers too parallel. By use of an oscillating device, one thin film, or sliver, of wool is placed diagonally and overlapping another sliver to give a crisscross effect to the fibers. This permits the fibers to be disentangled and somewhat parallel and at the same time provides a fuzzy surface to the yarn. After this process, the woolen slivers go directly to the spinning operation.

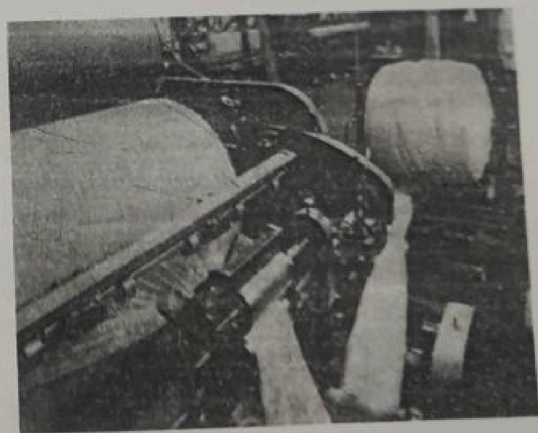
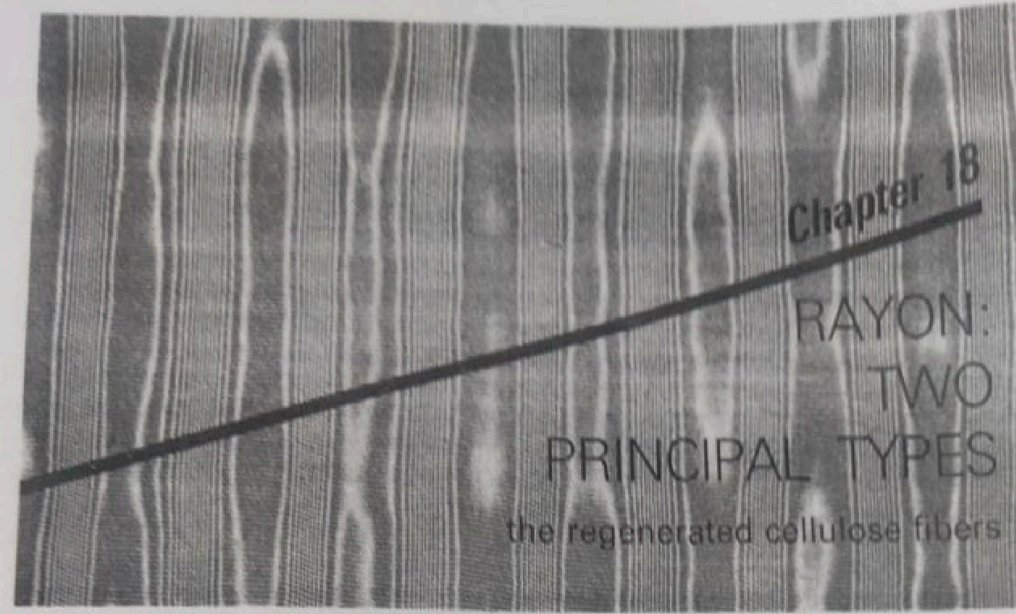


Figure 15-4 Carded wool in fine web form is drawn from the cylinder (left) into woolen sliver (right). *(Courtesy National Association of Wollen Manufacturers)*



Chapter 18

RAYON: TWO PRINCIPAL TYPES

the regenerated cellulose fibers

A rayon fiber is composed of pure cellulose, the substance of which the cell walls of such woody plants as trees and cotton are largely comprised. We are already familiar with cellulose in the form of such products as paper.

Rayon fibers are made from cellulose that has been re-formed, or *regenerated*; consequently, these fibers are identified as *regenerated cellulose fibers*.

HISTORY OF RAYONS

The production of a fiber such as rayon, the first of the manmade fibers, had been prophesied as long ago as 1664 by Robert Hooke, the English naturalist. He believed that it was possible to make an "artificial glutinous composition, much resembling, if not full as good, nay better, than that excrement, or whatever other substance it be out of which the silkworm wire-draws his clew." In 1710, René A. de Réaumur, the French scientist, suggested the possibility of making silk filaments out of gums and resins; for example, threads of varnish. One hundred and thirty years later, in 1840, an apparatus was invented that drew synthetic filaments through small holes. In 1855, Georges Audemars, a Swiss chemist, discovered how to make cellulose nitrate. This was the first step toward the nitrocellulose process of making rayon. Almost thirty years later, in 1884, Count Hilaire de Chardonnet produced the first manmade textile fibers from nitrocellulose. He became known as the "father of rayon." Chardonnet obtained the original French patent and won the financial support that built the world's first rayon factory. Yet, it ultimately was superseded by other types.

In 1890, L. H. Despaisses of France developed the cuprammonium process for making rayon, which had some properties that were superior to those of nitrocellulose rayon. Although it was initially not economically competitive to manufacture, improvements in the spinning technique developed in Germany resulted in successful commercial production there in 1919. Subsequently, cupram-

[illegible] rayon was produced in the United States but manufacture was discontinued in [illegible]. A relatively small amount of cuprammonium rayon is still produced in Germany and Japan.

Manmade textile filaments were officially recognized in 1925, when the Federal Trade Commission (FTC) permitted the use of the name "rayon" for yarns obtained from cellulose or its derivatives. As the production and types of manmade fibers had increased and been given various trademarks, the FTC ruled again in 1937 that any fiber or yarn produced chemically from cellulose must be designated as rayon.

Over the period of the next fifteen years, however, confusion developed among garment manufacturers, and particularly among consumers, because there were as many as four different types of rayon with some similar and some different properties. Some rayons would fade faster than others; some would dry more quickly than others; some would stick to the iron and melt, others would iron nicely. The cause of this lay in the fact that there were basically two groups of rayons: one consisting of regenerated pure cellulose, the other of a cellulose compound. These different compositions gave different properties. The FTC therefore ruled that as of February 9, 1952, there would be two categories of cellulose fibers: rayon and acetate. All fabrics and garments containing rayon and/or acetate must now be labeled as such and the percent of content of each fiber indicated. The rules also incorporated the first official designation of rayon and acetate products as manmade rather than synthetic. In the chemist's terminology, rayon and acetate are not synthetic because natural materials—cotton linters and wood pulp—are used in their manufacture, rather than chemical elements.

BASIC METHOD OF PRODUCING RAYON FILAMENT

The natural process by which the silkworm transforms the cellulose of mulberry trees into two fine filaments is simulated in the process of making rayon.

A liquid substance of cellulose is forced through a metal cap or nozzle about the size of a thimble. This nozzle is called a *spinneret* because it performs the same function as the silkworm's spinneret (see Figure 18-1). The cap is usually made of a platinum-rhodium alloy because that metal is not affected by acids or alkalies; it is perforated with small holes that are almost invisible to the naked eye. Through each of the tiny holes, a filament is extruded, which is solidified by a liquid bath as it comes from the spinneret. This is similar to the hardening by air of the raw-silk substance spun by the silkworm. The number of holes in the spinneret ranges from 1 to 20,000, and filaments of equal size are simultaneously produced. In a subsequent operation, these filaments are combined by twisting to make any required diameter of rayon yarn.

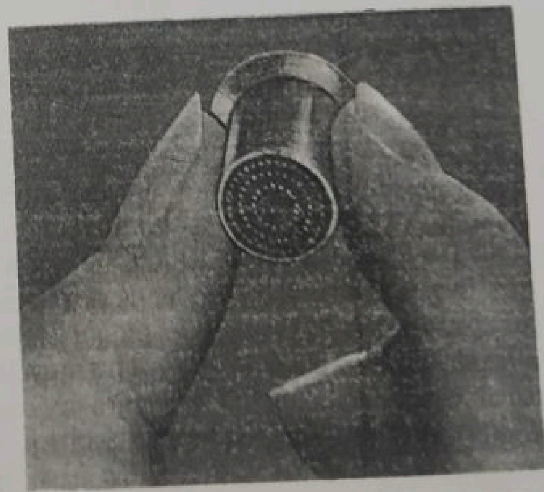


Figure 18-1 The spinneret that forms the spinning solution into filaments. (Courtesy Avtex Fibers Inc.)

TYPES OF RAYON

[illegible] The fibers differ in important characteristics because the methods differ in specific features of manufacture. These rayons—viscose and high wet-modulus—are classified as regenerated rayons because the original raw material (cellulose) is changed chemically into another form, which is then changed (regenerated) into cellulose again. These changes produce the final product—purified cellulose in fiber form.

VISCOSE RAYON

THE VISCOSE PROCESS

Viscose rayon is made from cotton fiber or wood pulp usually obtained from spruce, hemlock, and pine trees. The chemical process of dissolving wood pulp was first discovered in 1840 by F. G. Keller, a noted German weaver. The viscose method of using wood pulp to manufacture rayon was developed in 1892, more than fifty years later, by C. F. Cross and E. J. Bevan, both British scientists. The first viscose manufacturing plant in the United States was established in 1910.

In the viscose process, wood chips or cotton fibers are treated to produce sheets of purified cellulose that resemble white blotters. The cellulose sheets are then soaked in caustic soda, producing sheets of alkali cellulose. This substance is broken up into fluffy white flakes or grains called *cellulose crumbs*, which are aged for two or three days under controlled temperature and humidity. Liquid carbon disulfide is then added. This turns the cellulose into cellulose xanthate, a light-orange substance that is still in crumb form. The cellulose xanthate crumbs are dissolved in a weak solution of caustic soda and transformed into a thick viscous solution called *viscose*, resembling honey in color and consistency (see Figure 18-2). The viscose is aged, filtered, and vacuum-treated to remove air bubbles, as they would cause the filament to break. It is then forced through the holes of the spinneret into sulfuric acid, which coagulates the cellulose of the soluble cellulose xanthate to form pure regenerated cellulose filaments.

Controlled variations in certain characteristics of viscose rayon are possible. Illustrative of these are:

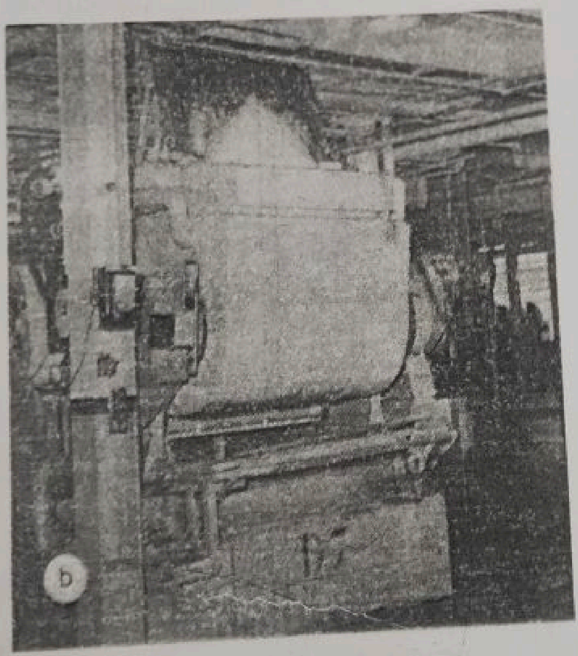
The luster can be regulated from *bright* to *semidull* or *dull*, depending upon the amount of delustering agent that is added to the viscose solution before extrusion through the spinneret.

Dyes may be added to the solution to produce *solution-dyed* filaments which have a high degree of color permanency.

Variations in the chemical composition of the coagulating bath cause different rates of coagulation on the inside and the outside of the fiber that result in variations in the thickness of the skin of the fiber; this in turn provides a *latent crimp* that will emerge when the fiber is immersed in water.

A technique of molecular blending may be used to increase absorbency. An "alloy" of natural and synthetic polymers may be engineered to form the viscose solution for the desired higher absorbency.

By adding sodium carbonate to the viscose solution and then passing it through the acid spinning bath, carbon dioxide gas is formed inside the fiber. This results in a hollow oval-shaped fiber which provides greater absorbency, greater bulk, and improved hand.



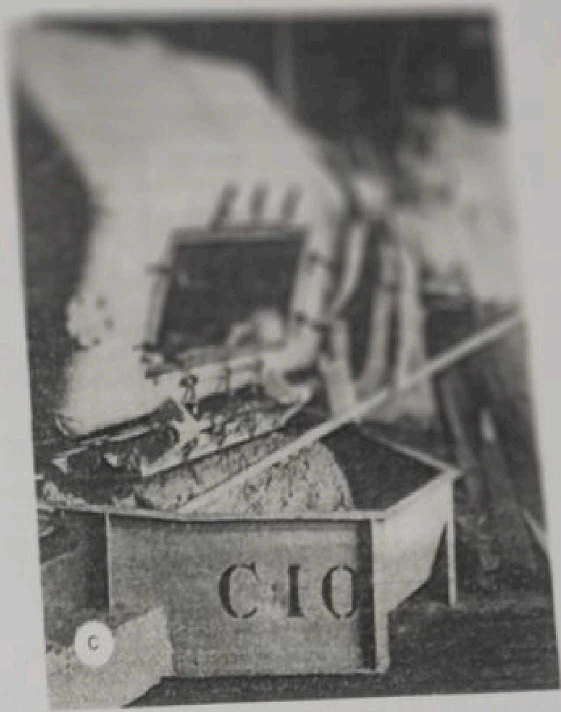


Figure 18-2 (a) To regenerate the cellulose for the viscose rayon process, cellulose sheets are soaked in caustic soda to produce alkali cellulose. *(Courtesy Avtex Fibers Inc.)* (b) Alkali cellulose crumbs are poured into a vat to be soaked in carbon disulfide, thus forming cellulose xanthate. (c) The cellulose xanthate crumbs are removed from the vat to be dissolved in weak caustic soda. *(Courtesy American Enka Co.)*

The diameter of the fiber may be varied to give a thick-and-thin effect by changing the pump pressure and drawing off the filaments as they are extruded.

The shape of the spinneret holes may be varied to change the appearance and hand of the fiber.

The strength, or *tenacity*, of the fiber may be increased by inducing thicker skin and even all-skin and by aligning the molecules through stretching to produce medium-tenacity fiber and the high-tenacity rayon for such purposes as tire cord.

Such variations in production techniques have increased the versatility of rayon and have made viscose rayon a major type of fiber. Further details regarding trademarks, manufacturers, types, characteristics, and uses are presented in Table 18-1.

TABLE 18-[illegible] VISCOSE RAYON TRADEMARKS (Continued)

TRADEMARK	MANUFACTURER	TYPE	SPECIAL CHARACTERISTICS	USES
Perlglo	American Enka Co.	Multifilament	Medium dull luster	Apparel, home furnishings
Skybloom	American Enka Co.	Staple	Very high crimp	Home furnishings
Softglo	American Enka Co.	Multifilament	Semidull	Apparel
Spunenka	American Enka Co.	Multifilament		Industrial fabrics
Super White	American Enka Co.	Staple	Bleached, optically brightened	Apparel

YARN PRODUCTION

Upon extrusion from the spinneret, the viscose rayon fibers are processed by one of several methods into filament or spun staple yarns (see Figure 18-3).

Processing

There are three methods of processing the viscose rayon into filament as the fiber is extruded (see Figure 18-4).

Pot, or Box, Spinning. The filaments are removed from the coagulating bath by being passed over a series of godet wheels. The resultant slight tension on the fibers causes a certain amount of molecular alignment and consequent strengthening of the filaments. The fibers are led through a funnel moving up and down in a covered cylinder called a *Topham box*, which whirls around and builds by centrifugal force a hollow cake of filament against the cylinder's wall. This action also gives the filaments a slight uniform twist. After the cake is removed, it is thoroughly washed, treated to remove any trace of residual chemical substances, bleached, rinsed, dried, and wound on spools.

Spool Spinning. The filaments may be drawn from the coagulating bath over guides and rollers and wound on perforated spools. A washing solution is forced through the spools' holes to cleanse filaments that are then bleached, rinsed, dried, and wound on cones or spools or put in skeins.

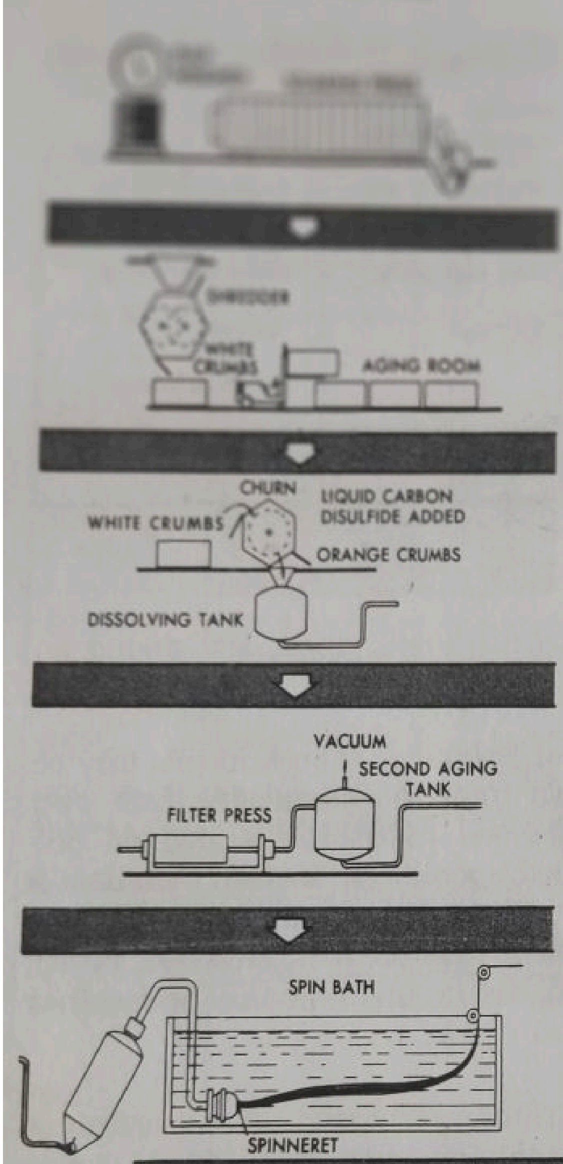
Continuous Process. Upon extrusion from the spinneret, the filaments may be carried in one continuous process over the godet wheels through a series of reels as they are washed, purified, bleached, dried, twisted, finished, and wound onto the desired package for the particular desired use. (This process is not included on the schematic shown in Figure 18-3.)

Filament Yarns

The rayon filament yarns are processed in a manner similar to thrown silk yarns. The filaments can be thrown, or twisted, as indicated in the pot and continuous spinning processes, or they may be thrown after being received in spool form.

The count of rayon yarn is expressed in denier (or in decitex) as explained in Chapter 16. The size of rayon yarn is controlled by the number and the size of holes in the spinneret. The number of denier required to weigh one skein of yarn, 450 meters long (the standard length), is the denier that indicates the size of the yarn in that skein. (The number of grams in one skein of yarn 10,000 meters in length is the number that indicates the decitex of the yarn in that skein.) Because the sizes of yarns differ according to the purposes for which the yarns are intended, the weights of the skeins differ even though the skeins are of the standard length. The finer the yarn, the less the skein weighs, and the lower the figure that expresses its weight and therefore its size in denier (or decitex).

Monofilament Yarns. The monofilament yarns are composed of a single filament. The viscous solution is extruded



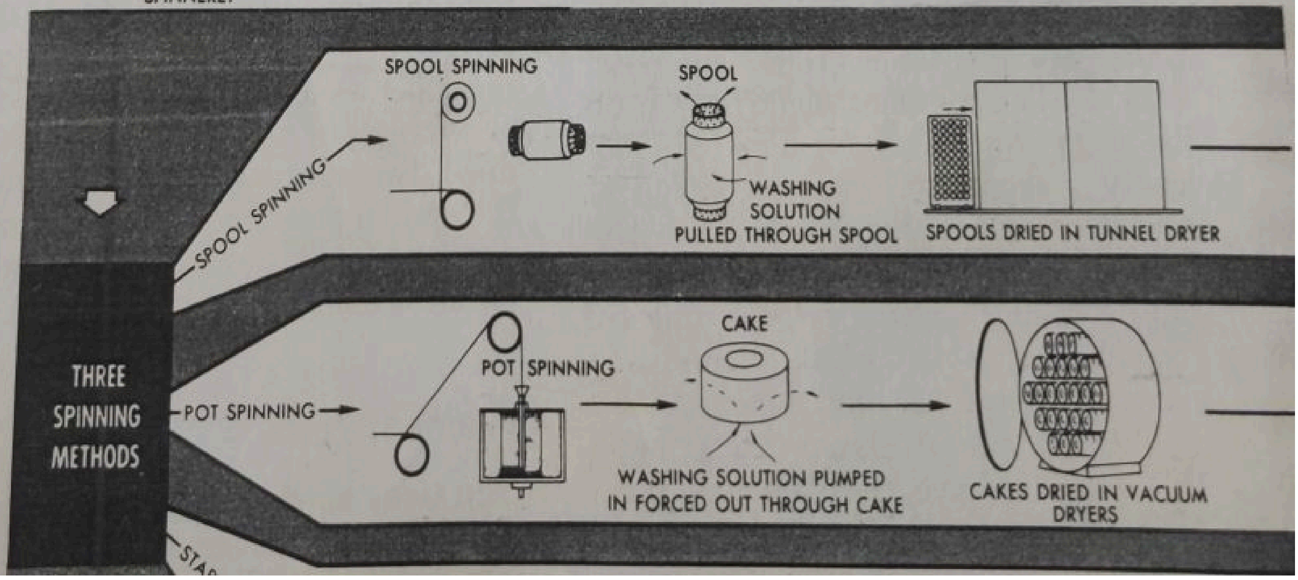


Figure 18-3 Production of viscose rayon yarn. (*Courtesy American Enka Co.*)

Figure 18-4 These photographs illustrate aspects of rayon fiber production. (*a*) Rayon filaments emerging from the sulfuric acid coagulating bath and passing over godet wheels. (*b*) A cake of filament rayon removed from the Topham box. (*Courtesy Avtex Fibers Inc.*)

through a spinneret with only one hole. Spinnerets, each with a different-sized hole, are used, depending on the denier of yarn desired. Monofilament yarn is used for a variety of products, including hosiery. The term "monofil" is applied to a type of monofilament yarn. (When the decitex system is used, monofilament is identified by "f 1" following the decitex number.)

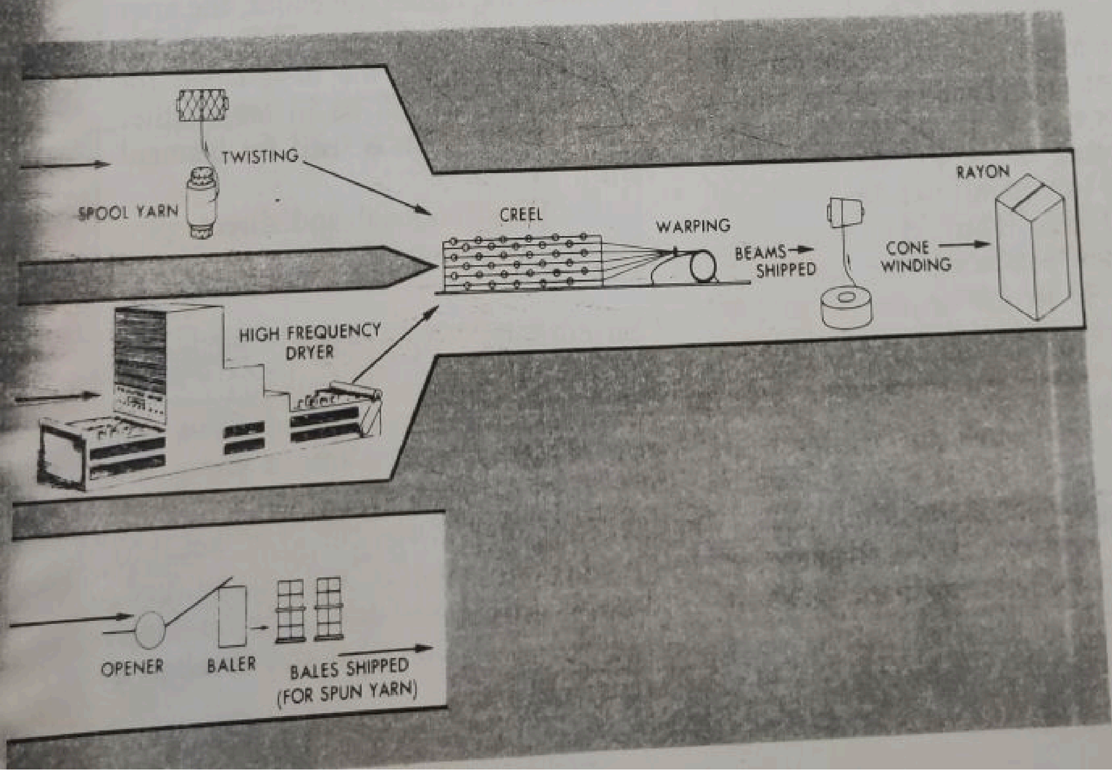



Figure 18-5 (a) Rayon tow, having been cut, washed, and dried, is moved by conveyor belt for baling. (b) A bale of rayon staple, from which spun yarn is made. (Courtesy Avtex Fibers Inc.)

Multifilament Yarns. The multifilament yarns are composed of more than one filament, usually a great many twisted together. These filaments are extremely fine, supple, pliable, and stronger than monofilament yarns of the same denier (or dtex). They are used for a wide variety of fabrics including sheers. The continuous-filament yarns may be used to produce smooth fabrics or creped-surface fabrics, depending upon the amount of twist given to the yarns.

Viscose rayon multifilament yarns to be used for apparel and upholstery fabrics are composed of 10 to 980 filaments, which may vary from 1 to 6 denier (about 1 to 7 dtex) each. Thus, when 40 or more filaments are combined, the yarns will vary from 40 to 240 denier (40 to 270 dtex). A yarn designated as 100/40 (111 dtex f 40) would be 100 denier (111 dtex) and be composed of 40 filaments.

Spun Yarns

The filament yarns can be adapted for other effects by reducing them to short lengths, usually 1 to 6 inches (25–150 mm), and spinning the staple similarly to the spinning of cotton or wool. The counts of spun rayon yarns conform to the base of the system used; for example, count Ne 1 would be 1 pound drawn 840 yards on the cotton system, 1600 yards on the woolen system, and 560 yards on the worsted system. In each of these systems, of course, the higher the count, the finer the spun yarn (see Figure 18-5). (If the tex system is used, the designation for spun rayon yarn will be in tex—rather than decitex, which is used for filament yarn.)

Both conventional and direct spinning methods are used.

Conventional Spinning. Filaments ranging from 1.5 to 50 denier (1.7 to 56 dtex) each may be gathered from the spool spinning process into a group, or *tow*, of 600 to 250,000 filaments. The tow may then be precision-cut while wet into predetermined lengths, washed, purified, bleached, rinsed, and dried. As the staple dries, it shrinks somewhat and develops a degree of crimp that facilitates later processing into yarn.

Some rayon fiber manufacturers process the tow through washing, purifying, bleaching, rinsing, drying, and then dry-cutting into predetermined staple lengths. This method has the disadvantage of producing uncrimped staple, but it permits production of staple as needed from stored tow. It also permits fiber processors, such as yarn manufacturers, to cut as much staple as they may need (see Figure 18-6).

Depending upon the kind of yarn desired, the staple must be spun on a cotton, woolen, or worsted system. The process conforms to the description of these methods of opening, breaking, carding, combing, and so forth, as described in Chapters 2 and 15.

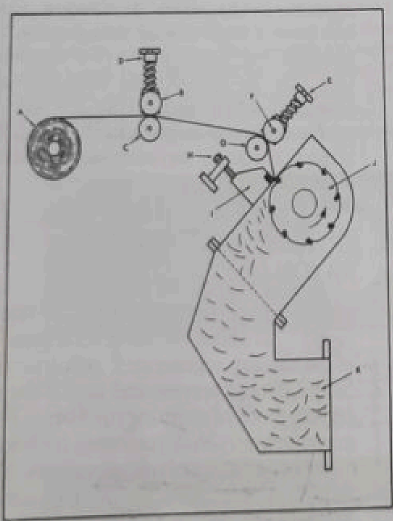


Figure 18-6 The operating sequence of a staple cutter is as follows: (A) Reel of tow; (B) Top pull roll under spring pressure; (C) Bottom pull roll; (D) Adjusting screw for top pull roll; (E) Adjusting screw for top tension roll; (F) Top tension roll; (G) Bottom tension roll; (H) Bed knife adjusting screw; (I) Bed knife with hardened insert; (J) Rotating cutterhead, with eight fly knives making a shearing cut across the fiber; (K) Discharge chute with flanged outlet for air suction. *(Courtesy Taylor, Stiles & Co.)*

Such spun rayon yarns have a different character from the filament rayon yarns. According to the amount of twist inserted in the spinning process, spun rayon yarn can be made stronger, less lustrous, and adaptable to napping and other finishes, producing fabrics that resemble wool, linen, or cotton. Such short-staple rayon can also be combined with any of the other fibers to make effective and useful fabrics. This blending would not be possible with the long rayon filament. Thus, spun rayon provides new finishes and a variety of low-priced fabrics that formerly were made only from natural fibers.

Direct Spinning. A more economical method of producing spun yarn is to reduce the filaments in the tow to staple without disturbing the parallelism of the fibers. This eliminates the need for opening and breaking, and since the fibers are of desired length and have no foreign matter or neps, the carding and combing operations are also unnecessary. There are three basic methods of accomplishing this:

1. The tow may be converted into staple by cutting the filaments into either uniform or varied lengths of up to 6 inches (150 mm). This method permits blending with other fibers and produces a crimped sliver (see Figure 18-7). The sliver is then passed along for further processing into cotton, woolen, or worsted-type yarn of high quality with excellent uniformity of evenness and count.
2. The tow filaments may be broken into staple by the Perlock process. The technique is the same as that described on

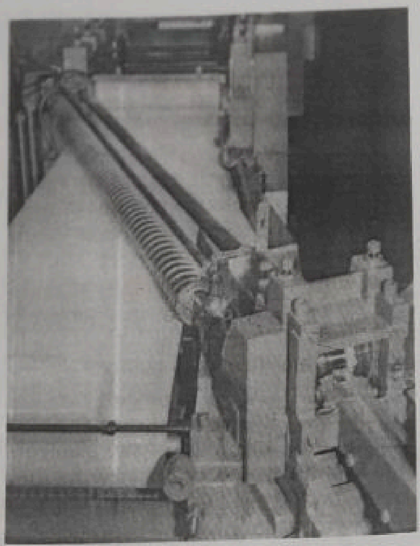


Figure 18-7 Close-up of converted tow crimped and cut into staple being rolled diagonally upon itself to form a continuous sliver of staple fiber. (Courtesy Warner & Swasey Textile Machine Co.)

page 64 for the production of high-bulk yarn. Figure 18-8 indicates the movement of the tow through the breaking zone where tension is applied suddenly between the break bars and the front rolls, which causes the individual filaments to break at their weakest points. This results in random breakage of the fiber into staple without disturbing their parallelism. The process is repeated as the staple is moved along to a crimper, where it emerges as crimped sliver. The sliver is then spun into yarn using any one of the desired spinning systems.

3. Another technique of reducing tow to staple is based upon the Perlock process but uses the Direct Spinner (see Figure 18-9). This method is in much less use because the staple and yarn produced have certain limitations, as will be noted in the following description.

Tow is fed from one set of rolls onto a conveyor belt, then to a second set of rolls moving at a higher rate of speed. The tension created by this difference in speed and the grip exerted by the faster rolls cause the random breakage of the fibers at their weakest points. The fibers are then drafted into sliver form and directly spun in the conventional manner. However, with this procedure, it is not possible to blend the staple with other fibers. It may also be noted that the staple does not have any crimp.

Since the filaments are stretched to the breaking point and the fibers are then twisted into yarn without having sufficient opportunity to relax, direct-spun yarns will have a high rate of shrinkage in the wet-finishing processes. This disadvantage may be turned into an advantage, especially when such yarns are used to produce novelty nubby effects in fabrics, creped surfaces, or compact constructions.

TRADEMARKS OF VISCOSE RAYON

Many companies manufacture viscose rayon. All utilize the same basic principle of producing regenerated cellulose fiber by the viscose process and any of the several methods of spinning the fiber. These manufacturers have registered trademarks for their respective viscose rayon fibers and yarns in order to identify and promote their products. Trademarks identify variations in production that affect certain characteristics of the fibers and yarns, such as dull, staple, crimp, solution-dyed, or high tenacity. While the retailer and the consumer will find fabrics and garments advertised, labeled, or tagged with these trademarks, all viscose rayon of the same type has relatively similar quality and properties. Acquaintance with these

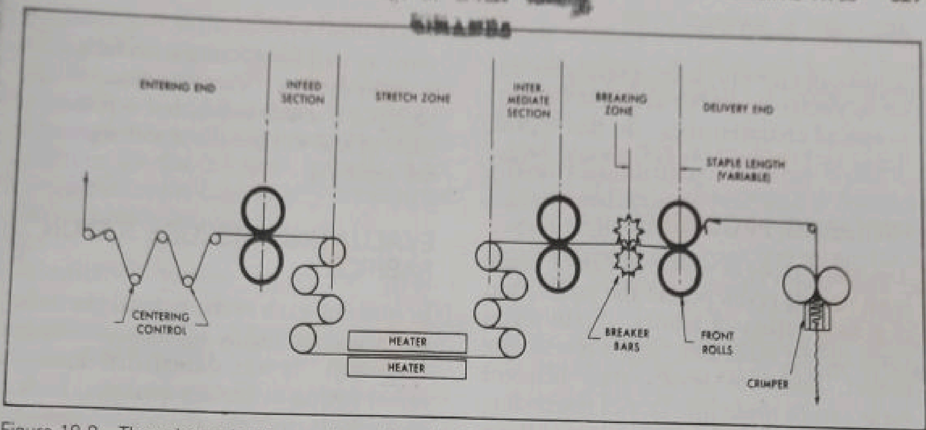


Figure 18-8 The schematic diagram shows how the Turbo Stapler reduces tow to sliver in one machine by the Perlock principle. This action takes place in the breaking zone and may be described as a modified, controlled-stretch breaking process. To understand the process, visualize a single fiber-end as it leaves the intermediate nip rolls. It passes between the breaker bars and approaches the front roll nip, being carried under practically no tension by adjacent fibers. As it enters the front rolls, tension is suddenly applied and a break occurs in the area of stress concentration created by the abrasive breaker strips. This fiber, now reduced to staple length, is rapidly carried through the front rolls. The original end, from which it came, is again carried toward the front rolls, and the process repeats. Each end in the tow is exposed to the same process, but the breaks occur at different, perfectly random times. There are, therefore, no coterminal fibers, and evenness and parallelism are excellent. *(Courtesy Turbo Machine Co.)*

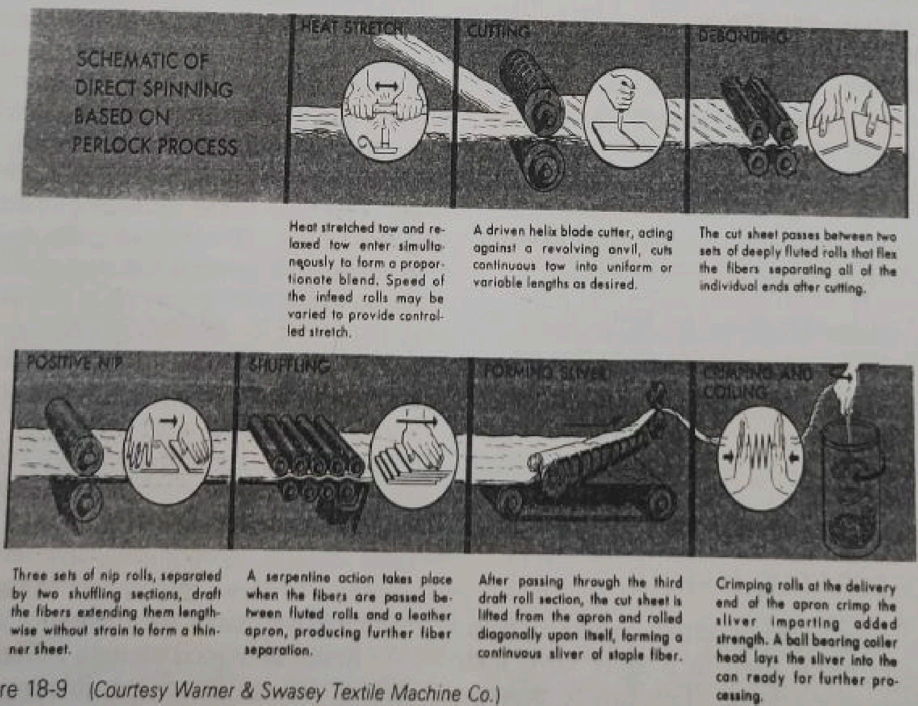


Figure 18-9 *(Courtesy Warner & Swasey Textile Machine Co.)*

names helps not only in recognizing the textile as viscose rayon but also in being alert to special characteristics. In this regard, Table 18-1 (pages 314–315) should help.

FINISHING PROCESSES

The many types of yarn that can be made from viscose rayon permit the production of a wide variety of fabrics. Spun rayon yarns can be made into fabrics resembling cotton, linen, or wool; rayon filament yarns can be made into fabrics resembling silk. To enhance the appearance of these fabrics and to improve their serviceability, they can be given various finishes. The most common finishes are as follows:

Calendering—for smoothness

Embossing—for decorative effects

Flame retardancy—for fire protection

Napping (spun rayons only)—for softness and warmth and to improve resemblance to wool

Preshrinking—for greater dimensional stability

Stiffening—for body

Water repellency—for resistance to water and rain

Wrinkle resistance—for better shape retention

These finishes are discussed in greater detail in Chapters 9 and 10. Dyeing and printing procedures are discussed in Chapters 11 and 12, respectively.

DECORATIVE EFFECTS

Viscose rayon is often combined with other textile fibers to produce novel and decorative effects. This can be accomplished by combining different types of yarns as well as by using such techniques as cross-dyeing. Viscose rayon can also be given a moiré finish, but it is not permanent and will come out with washing or dry cleaning.

EVALUATING VISCOSE RAYON FABRICS

In studying each of the natural fibers, cotton was rated highly for its economy and versatility. It was shown that linen excelled cotton in certain qualities, such as strength, luster, absorbency, cleanliness, and crispness. With respect to warmth and resiliency, wool and silk rank first.

The development of a manmade fiber possessing many of the above-mentioned prized qualities of the natural fibers is a tribute to human ingenuity. If the supply of natural fibers were insufficient or even nonexistent, manmade fibers could fully meet the situation.

Variations in the properties of viscose rayon are directly dependent upon the kind of fiber desired. Similar viscose rayon fibers have similar properties. Of course, the type of yarn that is used, as well as how the material is constructed, will contribute to the ultimate properties of the fabrics. The following discussion represents, in general, the properties of viscose rayon.

Strength. The tensile strength of viscose rayon is greater than that of wool, but is only about half as great as that of silk. Viscose rayon is also weaker than cotton and linen and its strength is reduced 40 to 70 percent when wet. Yet it produces fairly durable, economical, and serviceable fabrics whose smoothness of surface favorably withstands the friction of wear.

Reasonably good strength with sheerness of construction is possible in rayon fabrics by means of multifilament yarns.

High-tenacity yarns afford a lightness with strength that surpasses silk.

Smooth-surfaced rayon fabrics are very slippery, and therefore, the seams of rayon garments will slip unless the French seam or the flat-fell seam is used. Also, when cut on the bias, loosely constructed rayon fabrics may slip.

Elasticity. Viscose rayon has greater elasticity than cotton or linen but less than wool or silk. Therefore, while viscose rayon fabrics have some inherent extensibility, undue strain might cause them to sag and even burst. High-tenacity rayon is generally less elastic than regular rayon.

Resilience. Viscose rayon lacks the resilience natural to wool and silk and creases readily; but it should be remembered that the resistance of a fabric to creasing depends on the kind of yarn, weave, and finishing process. For example, the extremely fine filaments used in multifilament rayons have a greater resistance to creasing, and any of the crepe surfaces produced by tightly twisted yarns also resist creasing. Fabrics treated with one of the better patented crease-resistant finishing processes are highly resistant to creasing. Also, a soft surface produced by napping, typical of spun rayon, has some degree of crease resistance because of the softness and flexibility of the short staple, which recovers easily from wrinkles. Crimped staple offers increased resilience to spun yarn.

Drapability. Viscose rayon possesses a marked quality of drapability because it is a relatively heavyweight fabric. The filament can be made as coarse as desired, depending on the holes in the spinneret; and the yarn can be made heavy without the use of metallic filling, thus producing body substance in the fabric. Higher tenacity rayons are stiffer and do not have the good draping quality of regular viscose rayons.

Heat Conductivity. Viscose rayon is a good conductor of heat and is therefore appropriate for summer clothing. Spun rayon fabrics, however, are adaptable to winter apparel because they can be napped. The fuzzy surface provides some insulation, although the warmth will certainly not be as great as can be provided by wool or silk.

Absorbency. Viscose rayon is one of the most absorbent of all textiles. It is more absorbent than cotton or linen and is exceeded in absorbency only by wool and silk. The combination of high heat conductivity and high absorbency of rayon makes it very suitable for summer wear. However, the loss of strength when wet places a limitation on its use where strain upon the fabric would be a factor. Also, viscose rayon tends to have a slick, sometimes sleazy hand when wet. Besides, as viscose rayon absorbs moisture from the air, there is a tendency to sag; but as the humidity reduces, the fabric shortens. This presents a disadvantage for its utilization in curtains.

High-absorbency variants, such as Fibro HSO, can absorb up to 30 percent more moisture than regular viscose, and Fibro S.I., which is used for sanitary nonwovens, can absorb at least two and one-half times as much moisture as standard viscose rayon.

Cleanliness and Washability. Because of its smoothness, viscose rayon fiber helps to produce hygienic fabrics that shed dirt. Some viscose rayon fabrics wash easily; and depending on the finish that may be given to them, they will not become yellow when washed or dry-cleaned. White viscose rayon remains white and therefore needs no bleaching. Since viscose rayon temporarily loses strength when wet, it must be handled with care when washed. When laundered, a mild soap or detergent and warm water should be used. The garments should be squeezed, not wrung, to remove the water. When in doubt about whether a garment should be washed, it is safer to dry clean it, because viscose rayon dry cleans very well.

Reaction to Bleaches. It has been mentioned that white viscose rayon does not normally discolor. However, with prolonged exposure to sunlight, certain finishes or blends with such fibers as cotton may show some discoloration. Household bleaches containing either sodium hypochlorite (such as Clorox), sodium perborate (such as Snowy), or hydrogen peroxide may safely be used. However, it is always advisable to be careful of the amount of bleach used as well as the temperature of the water.

Shrinkage. Viscose rayon fabrics tend to shrink more than cotton fabrics of similar construction. Crepe weaves and knitted fabrics always shrink more than flat-woven fabrics because of the nature of the construction. Spun viscose rayon fabrics shrink more with repeated laundering than fabrics made of the filament yarns. Spun viscose rayon fabrics can be given a shrink-resistant finish, such as Sanforset, which makes them suitable for apparel that must be frequently washed. When spun viscose rayon is blended with wool, the great amount of shrinkage characteristic of the wool is reduced.

Effect of Heat. Since viscose rayon is a pure cellulose fiber, it will burn in much the same manner as cotton. Napped or pile viscose rayon fabrics are susceptible to flash burning and must therefore be given a flame-resistant finish. Application of heat at 300°F (150°C) causes viscose rayon to lose strength; above 350°F (177°C), it begins to decompose. When ironing, it is wise to use either a moderately hot iron on a dampened fabric or a steam iron.

Effect of Light. Viscose rayon has generally good resistance to sunlight, though prolonged exposure of intermediate-tenacity rayon results in faster deterioration and yellowing.

Resistance to Mildew. Like cotton, viscose rayon has a tendency to mildew. Such fabrics, therefore, should not be allowed to remain damp for any length of time.

Resistance to Insects. Moths are not attracted to cellulose. Consequently, moth-proofing treatments are not necessary for viscose rayon. Resistance to other insects is also similar to that of cotton. Rayon can be attacked by silverfish.

Reaction to Alkalies. Concentrated solutions of alkalies disintegrate viscose rayon. A mild soap and lukewarm water is therefore recommended when laundering such garments.

Reaction to Acids. Viscose rayon reacts to acids in a manner similar to cotton. Being pure cellulose, the fabric is disintegrated by hot dilute and cold concentrated acids.

Affinity for Dyes. Viscose rayon fabrics absorb dyes evenly and can be dyed with a variety of dyes, such as direct, acid, chrome, and disperse. Colored viscose rayons have a high resistance to sunlight, they withstand strong light better than silk. This property makes them suitable for window curtains. Of course, over a period of time, viscose rayon fabrics will fade. To overcome this, solution-dyed rayon, in which the dyestuff is put into the spinning solution thus becoming an integral part of the fiber, was developed. Solution-dyed viscose rayons, such as those produced under the trademarks of Coloray and Kolorbon, are absolutely fast to light, washing, atmospheric gases, perspiration, crocking, and dry cleaning. However, solution-dyed rayons are not produced in large quantities and are not widely used because there is not a large sustained demand for specific shades.

Resistance to Perspiration. Viscose rayon is fairly resistant to deterioration from perspiration. The color, however, is not usually as resistant as the fabric and will fade if not solution-dyed.

Figure 18-10 Good drape, body, and comfort are provided in fabrics of a 50/50 blend of the rayon variant, Fibro HSO, and polyester for such diverse apparel as (a) housecoats and (b) suits. *(Courtesy Courtaulds North America Inc.)*

VISCOSE RAYON BLENDS

Viscose rayon is blended as staple with a wide variety of fibers. Among the natural fibers, it is most frequently blended with cotton, to a lesser extent with wool, and occasionally with linen for special effects. The principal advantage afforded by rayon is lower cost. It may also be used to add luster, color, and textural effects. Variants may be blended with other fibers for special purposes. For example, high-absorbency Fibro HSO may be blended with polyester to obtain greater absorbency and comfort (Figure 18-10).

HIGH WET-MODULUS (HWM) RAYON

Several properties of viscose rayon represent limitations, particularly for its use as a substitute for cotton. The most significant limitation is its wet strength: viscose rayon loses up to 70 percent of its strength while wet. The tensile strength of a fiber is identified as its *tensile modulus*—the relative amount of pulling force that it can endure before breaking.

In 1960, commercial production was initiated for a rayon that approximated the natural strength of cotton and retained most of that strength, even when wet. It was consequently identified as a *high wet-modulus*, or HWM, *rayon*. Subsequently, it also became known as a *modified rayon*.

There are two varieties of this type of rayon in commercial production in the United States: Zantrel 700 and Avril. While both are cellulosic and have basic characteristics similar to high-grade cotton, they do differ from each other in certain respects.

Zantrel Rayon

The development of Zantrel rayon originated with the research of a brilliant Japanese scientist, Dr. Shozo Tachikawa. In 1938 he began experimentation in his own laboratory to produce manmade cotton, and by 1951 he had made considerable progress. However, because his laboratory techniques were impractical for commercial production, a European textile firm, CTA, subsequently acquired an option to the patents and adapted Tachikawa's laboratory techniques to commercial production. By 1958, CTA had developed a process for the manufacture of the fiber, identified as Z-54.

A license to produce the fiber in the United States was obtained in 1959 by the Hartford Fibers Co. Commercial production, begun in 1960 under the trademark of *Zantrel*, was subsequently acquired by the American Enka Co. It is now produced under the trademark of Fiber 700. Yarns and fabrics containing Fiber 700 that meet construction and performance standards set by American Enka Co. may be identified by the trademark Zantrel 700.

METHOD OF MANUFACTURE OF ZANTREL 700 RAYON

The production of Zantrel 700 rayon fiber requires the use of much highly specialized, costly equipment. Treatment of the purified cellulose requires different chemical compositions, concentrations, and temperatures, as well as much greater critical control of the process than is required for viscose rayon.

The objective of the process is to control the cellulose molecular length and arrangement in the fiber, for the longer the chain of molecules and the more longitudinally parallel they can be made to each other the stronger the fiber will be. The [illegible] polymers so that they tend to [illegible] out and lie parallel to each other. When these cellulose polymers become parallel, they tend to group into bundles forming chemical bonds along the length of the fiber. The object is to achieve a desired amount of such orientation and bonding. This organization of fairly long-chain molecules into connecting groups, or bundles, forms a microfibrillar structure resembling that of cotton.

The similar structures of Zantrel high wet-modulus fiber and cotton fiber account for the difference between this type of rayon and viscose rayon. The long-chain molecular structure has a greater number of and stronger chemical bonds between the molecules, which are arranged into fibrils that are compactly spaced and rather uniform in size and distribution. This structure inhibits such swelling agents as water and alkalies from readily penetrating between the cellulose molecules and thereby weakening the chemical bonds that hold the structure together. There is, then, much less loss of strength in Zantrel when it is wet than occurs in viscose rayon, which is composed of small bundles of shorter cellulose molecules, irregularly distributed and so with fewer and weaker chemical bonds.

ZANTREL RAYON YARN PRODUCTION

Zantrel fiber, which is produced in 1.0, 1.5, and 3.0 denier (0.9, 1.7, and 3.3 dtex), is cut into staple ranging from 1¼- to 2-inch (30–50 mm) lengths. It may be processed into yarn on any of the conventional spinning systems. It may also be spun in blends with cotton or other manmade fibers.

FINISHING FABRICS OF ZANTREL RAYON

The finishing processes given to Zantrel and Zantrel blend fabrics vary with the composition of the fabric and its desired end use. Listed below are some typical finishes:

Bleaching—for whiteness

Calendering—for smoothness

Compressive shrinkage—for greater dimensional stability

Plissé—for crinkle-textured effects

Resin impregnation—for wrinkle resistance and wash and wear care

Singeing—for a clear, smooth surface

These finishes are more fully discussed in Chapters 9 and 10. Wrinkle-resistant resin treatments need only a light application to fabrics of Zantrel to obtain the desired results, and the fabrics are not weakened by the finish as much as is cotton. Fabrics of 100 percent Zantrel are not mercerized. However, blends of Zantrel and cotton may be mercerized to give improved luster and strength to the cotton.

EVALUATING FABRICS OF ZANTREL RAYON

Zantrel fabrics fall into the price range of combed cotton. They have a natural, soft luster and smooth, soft hand. The quality of the fabric will, of course, be affected by such factors of yarn and fabric construction as were previously considered. The following characteristics and performances may be expected of Zantrel rayon fabrics.

Strength. Zantrel is approximately as strong as Upland cotton, and it is considerably stronger than regular viscose rayon. A major feature is its relatively high wet strength. Zantrel loses some strength when wet but not as significantly as viscose.

The abrasion resistance of Zantrel fabrics is somewhat lower than that of similar cotton fabrics. Fabrics of 100 percent Zantrel are therefore not well suited for apparel that is expected to be hard-wearing, such as children's clothes or workclothes.

Elasticity. Zantrel is less elastic than viscose rayon but slightly more elastic than cotton. In this regard, fabrics of Zantrel tend not to sag but rather to hold their dimension.

Resilience. Fabrics of Zantrel have some natural wrinkle resistance that is slightly better than viscose rayon. This may be enhanced without great loss of strength by the application of a wrinkle-resistant resin finish.

Drapability. Fabrics of Zantrel fiber are highly drapable. They have a markedly better drape than viscose rayon, as well as having a supple, firm hand.

Heat Conductivity. Being a cellulose fiber, Zantrel is a good conductor of heat. It has a cool, comfortable feel and is suitable for warm weather.

Absorbency. Due to its molecular structure, Zantrel is a little less absorbent than viscose rayon or cotton. Nevertheless, it is sufficiently absorbent to feel comfortable in warm, humid weather. Since Zantrel does not swell as much as viscose rayon when wet, there is less tendency to distort or sag.

Cleanliness and Washability. Because Zantrel fiber is round and has a smooth [illegible] reasonable care should be taken in laundering it to avoid heavy rubbing action, pulling, or twisting. Soaps and detergents used for cotton may also be used for Zantrel fabrics. Wash and wear characteristics may be imparted by using an appropriate resin finish, which has a less weakening effect on Zantrel than occurs on viscose rayon or on cotton.

Reaction to Bleaches. Many household bleaches, such as those containing sodium hypochlorite, are not too effective on fabrics of Zantrel, though they may be used. Peroxide bleach should not be used. The most desirable bleaches are sodium chlorite and paracetic acid, which are generally used only commercially.

Shrinkage. Like other cellulose fibers, Zantrel will shrink. However, Zantrel fabrics can be given a compressive-shrinkage finish, such as Sanforized, so that the residual shrinkage may be as little as 1 percent.

Effect of Heat. Fabrics of Zantrel scorch at 400°F (204°C) and burn at 465°F (240°C). These fabrics should be ironed at the "rayon" setting. When Zantrel does ignite, it burns in the same manner as other cellulose fibers.

Effect of Light. Zantrel has good resistance to light, similar to that of other cellulose fibers. For most apparel and decorative purposes, this is quite adequate. However, since prolonged exposure will weaken the fiber, it is not suitable for such outdoor purposes as awnings.

Resistance to Mildew. Like other cellulosic fibers, Zantrel will be damaged by mildew. Damp conditions should be avoided.

Resistance to Insects. Being a cellulosic fiber, Zantrel is not attacked by moth larvae and its resistance to other insects is similar to cotton.

Reaction to Alkalies. One of the desirable features of Zantrel is its good resistance to alkalies. This characteristic makes it possible to mercerize fabrics blended of cotton and Zantrel to obtain increased luster and strength in the cotton as well as an increased dye level in the blend.

Reaction to Acids. Zantrel reacts to acids in a manner similar to that of the other cellulose fibers. Hot dilute acids or cold concentrated weak acids will disintegrate the fiber.

Affinity for Dyes. Zantrel can be readily colored with a wide range of dyes, such as used for other cellulosics. Fabrics that have been vat-dyed have generally good all-around colorfastness.

Resistance to Perspiration. Zantrel is fairly resistant; however, it is deteriorated by acid perspiration.

ZANTREL RAYON FIBER BLENDS

Zantrel fiber is readily blended with a wide variety of other fibers because it can be easily spun on any conventional system and reacts favorably to the usual finishing and dyeing techniques. It can be blended with cotton, triacetate, nylon, polyester, and acrylic fibers. Depending upon the blend percentage, Zantrel may impart a crisp or lofty hand and a luster ranging from that of high-grade cotton to silk. A blend of 40 percent Zantrel and 60 percent carded cotton, for example, will produce a fabric that has a hand as good as or superior to that of 100 percent combed cotton and has the sheen of Pima cotton.

Avril Rayons

After several years of research and development, in 1961 the American Viscose Corp. produced a high wet-modulus rayon. Following several reorganizations, Avtex Fibers Inc. was formed and it produced the corporation's *Fiber 40* high wet-modulus rayon. Further developments led to the production of three types. Avtex Fibers Inc. produces these three types of high wet-modulus rayon identified as Fiber 40, Natural Multilobe HWM, and Prima. These staples are sold to processors and when the yarns and fabrics produced from these fibers are processed and finished according to Avtex's quality control standards, the products are marketed respectively under the trademarks of Avril, Avril III, and Avril Prima to identify them as high-performance rayons.

METHOD OF MANUFACTURE OF AVRIL RAYONS

The high wet-modulus rayons produced by Avtex are made from purified rayon pulp by certain patented modifications of the basic viscose process. The high wet-modulus rayon processes are employed to produce fiber structures which are more ordered with respect to the cellulose molecular arrangement. The cellulose molecules in these fibers have a higher degree of polymerization, on average, than found in regular rayon. The improved structural order of these fibers results in higher tensile strength, a decreased level of water swelling, and higher wet-modulus.

High wet-modulus Avril rayons are produced in 1.5, 2.25, and 3.0 deniers (1.7, 2.5, and 3.3 dtex) and in staple lengths of 1 9/16 to 3 inches (4–8 cm) to meet the requirements for various spinning systems and fiber blends.

TYPES OF AVRIL RAYONS

Fiber 40 (Avril) rayon has a circular cross section and is structured with a skin comprising about 30 percent of the cross-sectional area. The skin contributes high toughness properties to the fiber.

Natural Multilobe HWM (Avril III) rayon is a unique fiber offering relatively high tenacity and wet-modulus with the capability of simulating the convolution effects of cotton fiber and conferring an excellent cottonlike fabric cover and improved aesthetic hand properties. The improved fabric cover results from the multilobed cross section, which provides bulk characteristics, and the delustrant in the fiber.

Avril Prima rayon also offers a relatively high tenacity and the highest wet-modulus of the group of fibers. In addition, the fiber is chemically crimped [about 20 crimps per inch (cpi)] which causes bulking of fabrics during relaxed finishing, making it particularly suitable for knitted fabric structures.

AVRIL RAYON YARN PRODUCTION

A choice of staple fiber lengths can be made to meet the requirements for various spinning systems and fiber blends.

High wet-modulus fibers can be processed on the conventional ring and open-end spinning systems.

FINISHING FABRICS OF AVRIL RAYONS

These fabrics are finished in the same manner as viscose rayon or cotton. Since Avril rayon is whiter than cotton, bleaching is generally not required unless a higher level of whiteness is desired. Other finishes include the following:

Calendering—for smoothness

Compressive shrinkage—for greater dimensional stability

Plissé—for crinkle-textured effect

Resin impregnation—for wrinkle resistance; wash and wear care

Schreinerizing—for increased luster

Fabrics containing Avril/cotton blended yarns may also be mercerized to enhance their appearance.

EVALUATING FABRICS MADE WITH AVRIL RAYONS

Avril (Fiber 40) fabrics have a silky, lustrous appearance and a soft hand. They are made in a variety of lightweight as well as heavier weight fabrics comprising 100 percent rayon and blends with either polyester or cotton.

Avril III (Natural Multilobe HWM) fabrics are more cottonlike than any other type of rayon fabric. These fabrics are outstanding with respect to fabric cover and aesthetically have fuller hand than other rayons.

Avril Prima fabrics provide a wool-like hand and the highest dimensional stability of the group in laundering.

Judgments of performance of fabrics containing Avril rayon may be based upon the following characteristics.

Strength. The strength of Avril is about equal to Pima cotton and greater than Zantrel 700. When wet, Avril loses some strength. It remains, of course, much stronger than viscose rayon. Fabrics of Avril also have satisfactory abrasion resistance. They may therefore be expected to give good service in a variety of apparel from dresswear and sportswear to underwear and sleepwear.

Elasticity. Avril has very little elasticity, approximating that of cotton. Fabrics of Avril will not sag, which is an advantage in dress goods and draperies.

Resilience. Avril has better resilience than viscose rayon. Its resilience approximates that of Zantrel 700. When treated with a wrinkle-resistant finish, the resilience of Avril is also considerably improved with little loss of strength.

Drapability. Fabrics of Avril have a good hand with good draping quality. They have been found suitable for draperies as well as women's apparel.

Heat Conductivity. Like similar cellulose fibers, Avril is a good conductor of heat and is therefore quite well suited for warm-weather apparel.

Absorbency. Avril is as absorbent as viscose rayon. It is interesting to note, though, that despite the higher wet-modulus (strength) of Avril over Zantrel 700, Avril is more absorbent. This relatively high absorbency makes Avril well suited for a wide variety of apparel that may be comfortably worn in warm, humid weather. Avril can also be used for towels and sheets.

Cleanliness and Washability. Avril fiber has a smooth surface with a round to oval shape; therefore, it sheds dirt easily. On the other hand, its absorbency of water-borne substances may cause spotting. It launders readily, however, and is resistant to damage by detergents as well as to the machine washing action. Avril fabrics do not become harsh from repeated washings. Wash-and-wear finishes contribute to their easy care with much less loss of strength than occurs with cotton or viscose rayon.

Effect of Bleaches. With reasonable care, bleaches of sodium hypochlorite or sodium chlorite may be safely used. Hydrogen peroxide should not be used at home since special care must be given.

Shrinkage. Like other cellulose fibers, Avril rayon will shrink when wet. However, it can similarly be given a compressive-shrinkage finish so that it will have a residual shrinkage of less than 1 percent.

Effect of Heat. Fabrics of Avril scorch and flame at about the same temperature as viscose rayon. When pressing fabrics of Avril, the iron should be set at "rayon" and the fabrics should be damp.

Effect of Light. Avril, like other cellulose fibers, has good resistance to light.

Resistance to Mildew. Being a cellulose fiber, Avril will be attacked by mildew unless kept in a dry condition.

Resistance to Insects. Avril is not attacked by moth larvae and has the same resistance to insects as other cellulose fibers.

Reaction to Alkalies. Avril has very good resistance to damage by alkalies. Consequently, fabrics blended of Avril and cotton may be treated with caustic soda for mercerized and plissé finishes.

Reaction to Acids. Hot dilute acids or cold concentrated weak acids will destroy Avril fiber.

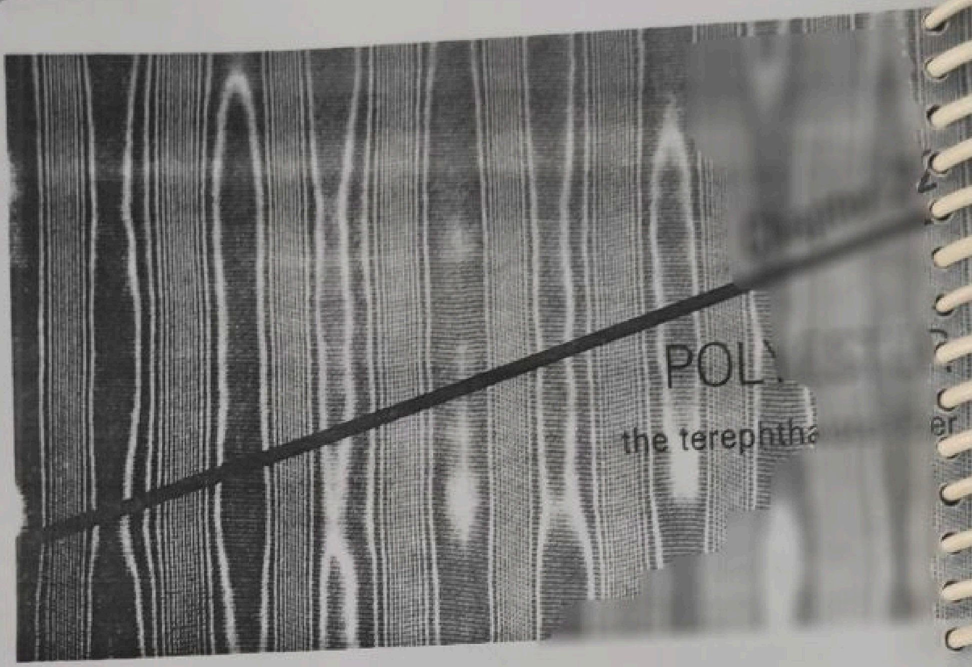
Affinity for Dyes. Fabrics of Avril can be dyed in a full range of shades with a wide variety of dyes used for other cellulose fibers. However, the fastness varies with the dye. Vat dyes, for example, provide good colorfastness.

Resistance to Perspiration. While Avril rayon is fairly resistant, it is affected by acid perspiration.

AVRIL RAYON FIBER BLENDS

Avril may be effectively blended with cotton to produce dimensionally stable fabrics. Avril contributes strength, improved luster, a soft hand, and an appearance of combed cotton to the blend. Resin-treated blends for wrinkle resistance and wash and wear care are stronger than similarly treated 100 percent cotton fabrics.

Blends of Avril and other manmade fibers have produced favorable results. For example, when blended with polyester, Avril generally adds comfort (due to its absorbency and draping quality), good appearance, pleasant hand, and strength.



Polyester fibers are long-chain polymers produced from elements derived from coal, air, water, and petroleum. As defined by the FTC, these fibers are chemically composed of "at least 85 percent b[illegible] weight of an ester of a substituted ar[illegible] matic carboxylic acid, including but [illegible] restricted to substituted terephthalate u[illegible] and para substituted hydroxybenzo[illegible] units." While it is difficult for the aver[illegible] consumer to comprehend this tech[illegible] definition, it is apparent that there [illegible] variations in the compositions and the[illegible] fore in the properties of polyester fib[illegible]

HISTORY OF POLYESTERS

The groundwork for the development of polyester fibers was laid by Dr. W. H. Carothers in his experiments with giant molecular structures. Seeing more immediate promise in the polyamides, he ultimately concentrated his research on them and, as a result, developed nylon. However, Dr. Carothers had published research information on polyesters, and

[illegible] cal form, [illegible] development [illegible] pany was comn[illegible] fiber, which is ca[illegible] day'kron).

Subsequently, other compa[illegible] came interested in polyester fib[illegible] 1958, Eastman Chemical Products, [illegible] announced its own version of po[illegible] which is called *Kodel*. The following year, the Celanese Corp. of America obtained licenses to use certain patents owned by Du Pont and entered the market with a polyester called *Fortrel*, which is now sold by the Celanese affiliate, Celanese Fibers Marketing Co. In 1966, American Enka Co. announced its *Enka* polyester fiber and Chemstrand Co., now Monsanto Textiles Co., introduced its *Blue "C"* polyester fiber, but subsequently discontinued this and other filament fibers in favor of certain staple polyester fibers such as *Spectran*. In 1967, the American Viscose Division of FMC Corp. (now Avtex Fibers Inc.) introduced its Fiber 200 polyester with the trademark *Avlin*, and Hoechst Fibers, Inc., (now Hoechst Fibers Industries) an outgrowth of an alliance between Hercules, Inc., and Farberwerke Hoechst AG, presented its *Trevira* polyester fiber. Since then, additional companies entered the polyester competition.

The polyester fibers produced by these companies may be primarily divided into two varieties: PET (polyethylene terephthalate) and PCDT (poly-1,4-cyclohexylene-dimethylene terephthalate). Most of the production is PET. Modification of each of these varieties is engineered to provide specific properties. It is also possible to produce other variants of polyester.

METHODS OF MANUFACTURE

Generally, each company produces only one variety of polyester, though there are likely to be modifications under specific trademarks. For example Dacron 51, a bright, high-tenacity PET polyester fiber is one of more than 70 variants of Dacron. (The reference to a number indicates the particular variant of that variety of polyester fiber.) One exception is Kodel polyester, which is produced as a Kodel 400 series (a PET variety) and a Kodel 200 series (a PCDT variety).

It is interesting to note that the same polyester used to produce a PET fiber is also made in thin, transparent film form. It is marketed under the trademark Mylar and used as a protective coating over metallic yarns, such as Lurex. Mylar is also used for magnetic tape for recording purposes.

PET Polyester

The process of manufacture of PET polyester fiber is similar to that of nylon, but the chemicals used are different (see Figure 22-1). The principal raw material is ethylene obtained from petroleum. The ethylene is oxidized to produce a glycol monomer dihydric alcohol that is then combined with another monomer, terephthalic acid, in an autoclave at a high temperature in a vacuum. Polymerization takes place with the aid of catalysts. The clear, colorless, molten polyester then flows from a slot in the vessel onto a casting wheel and forms into a ribbon as it cools to a porcelainlike hardness. The polymer is then cut into very small chips, dried to remove all traces of moisture, and blended for uniformity in preparation for spinning into yarn.

PCDT Polyester

The original PCDT polyester fiber is Kodel, which is now designated as the Kodel 200 series. This form of polyester is made by condensing terephthalic acid with 1,4-cyclohexane-dimethanol to form the tongue twister, poly-1,4-cyclohexylene-dimethylene terephthalate; hence, the convenient abbreviation PCDT polyester. As for PET polyester, PCDT is processed for melt spinning.

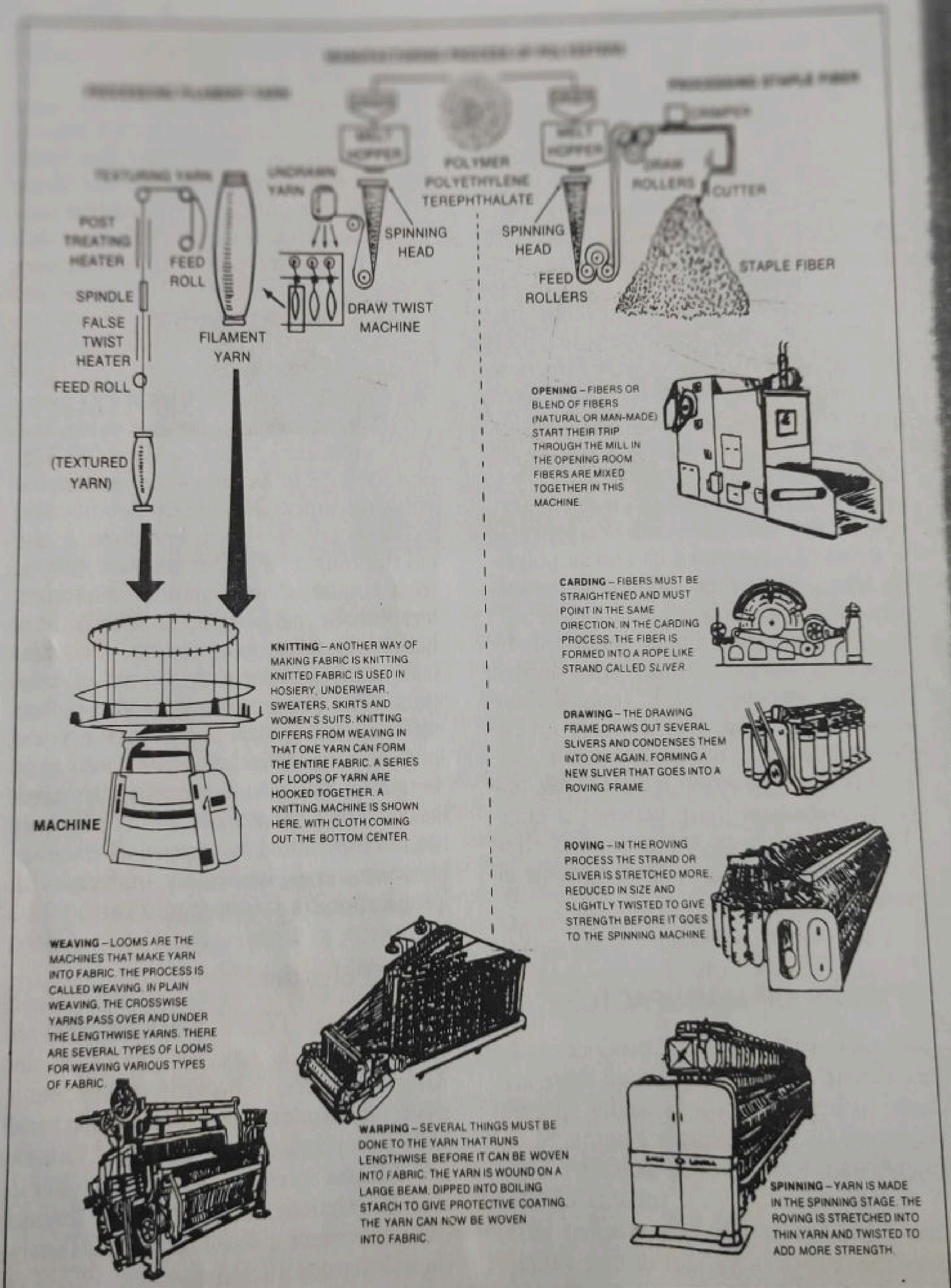


Figure 22-1 Manufacturing process of polyester fibers. *(Courtesy Celanese Fibers Marketing Co.)*

Spinning the Fiber

The molten polymer is rigorously maintained in an airtight condition, as oxygen will affect its stability. The spinning technique is similar to that used for nylon fibers. The viscous melt is extruded through a spinneret, and the filaments are subsequently drawn into the desired polyester fiber. Variations in the production process depend upon the desired end results.

The holes of the spinneret may be round or modified to be trilobal, pentalobal, hexalobal, or octalobal shapes to achieve specific effects, such as greater cover and opacity, enhancement or suppression of luster, wicking, comfort, and hand. The fibers may be produced hollow to give a large diameter with light weight and provide greater cushioning and insulative properties. Crimp may be developed to achieve crepe effects.

Other properties may be obtained with the aid of specific additives to the spinning solution. Polyester is normally a bright fiber, but it may be made semidull or dull by the addition of a delusterant. Certain additives may be included in the melt to alter the fiber's affinity for certain dyes. An antistatic substance may be included. The absorptive properties may be increased by other additives. A flame retardant may be added to the solution, as is done to produce such fibers as Trevira 271 staple and Trevira 692 partially oriented filament polyesters.

Drawing the Fiber

Upon extrusion from the spinneret, the polyester filament does not have all the desired characteristics because of the random arrangement of the superpolymer molecules. The fibers are therefore drawn, or elongated, with the aid of godet wheels, in the same manner as nylon fibers are drawn. The temperature conditions and the extent to which the fibers are drawn depend upon the properties desired. The polyester fibers are usually drawn to 5 times their original length (which results in a fiber diameter that is one-fifth the original size upon extrusion from the spinneret). If higher-tenacity fiber is to be produced, the filaments are drawn to a greater extent, as this increases the linear molecular orientation of the fiber. As they emerge from the drawing process and meet cold air, the filaments solidify.

Generally, the PET polyester filaments are drawn hot because this procedure produces more uniform fibers. However, when heavier diameters are desired, the monofilaments may be drawn at room temperture because the poor heat conductivity of the fiber results in irregularities in thick filaments that are drawn hot. PCDT (Kodel 200 series) polyester fibers are drawn at a higher temperature because of their higher melting point.

During the drawing process, the fibers may be textured. Draw-texturing saves steps, time, and production costs, and it gives the fiber producer greater quality control over the finished fiber. On the other hand, the fibers may be partially drawn, or oriented (see pages 52–53). Such POY production reduces investment costs for the producers and increases the flexibility and productivity of the texturizers.

TYPES OF POLYESTER YARN

The diameter of the polyester yarn is determined by (1) the rate of extrusion of the filaments from the spinneret, (2) the number of spinneret holes and therefore the number of filaments, and (3) the rate of drawing of the filaments. The yarns come in a wide range of diameters and sta-

EVALUATING POLYESTER FABRICS

The two major forms of polyester (PET and PCDT) have certain differences between them. These differences are principally in mechanical attributes rather than chemical. In general, the consumer may assume that the polyester being used is PET unless the fiber is identified as a Kodel 200 variety. Since Kodel polyester fiber comes in the two forms, 400 and 200, care instructions should be observed. It should be expected that the manufacturer will use the form of polyester better suited to the product.

It has been noted that polyester fiber is produced in both filament and staple form and that each form has certain properties that affect the appearance and performance of the finished fabric. Furthermore, some polyester filament and staple have properties designed for general consumer use while others are designed for industrial use. Within these two categories, there are further variations in properties. Therefore, while the ultimate user may be able to distinguish between fabrics of filament and spun yarn, one is not likely to be able to determine the particular variant of polyester used in order to anticipate the precise properties and the performance of the fabric. One must rely upon the manufacturer's ability to make the proper polyester fiber selection. Within this framework, the consumer may expect a certain range of characteristics and certain standards of performance of the polyester fabrics purchased. Some of these are general, others are specific.

Strength. As a group, polyester fibers may be characterized as relatively strong fibers. The PET polyesters are, in general, stronger than the PCDT Kodel 200 series polyesters.

Fabrics of regular tenacity PET polyester filament yarns are very strong and durable. The high-tenacity PET polyester filament yarns used for tires and industrial purposes are extremely strong; some types are the strongest of all textiles except glass, aramid, and certain highly specialized, exotic fibers not commonly used for consumer products. The staple fibers also vary in strength depending on the type of fiber. In general, PET polyester staple ranges from high-tenacity, which is stronger than nylon staple, to regular tenacity, which is about equal to or slightly weaker than nylon staple.

The abrasion resistance of polyester fiber is exceptionally good, being exceeded only by nylon among all of the commonly used fibers. However, the abrasion resistance of low-pilling types, including those of PCDT polyester is of a lower order that is generally similar to wool.

The strength, abrasion resistance, and stability of polyester make it very suitable for sewing thread. Such thread will not shrink and cause the fabric to pucker and it has adequate elasticity to yield to tension without resulting in loss of garment shape. The thread may be spun of polyester staple or core-spun of polyester filament core surrounded by cotton staple, to be selected for use as fabric composition and garment construction may require.

In summary, the tensile strength and abrasion resistance of polyester fiber are very good, and the fiber will provide relatively good service. PET polyester is superior in this regard to PCDT Kodel 200 series polyester.

Elasticity. Polyester fibers do not have a high degree of elasticity, although PCDT polyester is more elastic than PET polyester. In general, polyester fiber is characized as having a high degree of stretch resistance, which means that polyester fabrics are not likely to stretch out of shape too easily. This property makes polyester suited for knitted garments; sagging and stretching that would ordinarily occur are reduced. Fabrics of polyester fiber have good dimensional stability.

Resilience. Polyester fiber has a high degree of resilience. PCDT polyester is more resilient than PET polyester. Not only does a polyester fabric resist wrinkling when dry, it also resists wrinkling when wet. For example, a suit of polyester will keep its pressed appearance after many wearings, even after exposure to rain or moist, humid weather. And heat-set polyester fiber is suitably resilient for use in carpets.

Drapability. Fabrics of polyester filament yarn have satisfactory draping qualities. The trilobal filament type is more supple and imparts better drapability. Staple polyester can produce spun yarn that is more flexible and softer, thereby imparting the draping quality. Drapability of fabrics of blended polyester staple will depend upon the type and proportion of blend in the yarn as well as the fabric construction. (See Figure 22-4.)

Figure 22-4 This evening gown of Dacron polyester shows how well this fabric drapes. *(Courtesy E. I. du Pont de Nemours & Co.)*

Heat Conductivity. Fabrics of polyester fiber are better conductors of heat than fabrics made of acrylic fibers (discussed in Chapter 23). The basic polyester filament fiber is round. This results in a smoother yarn woven into fabrics with fewer air spaces and less insulation. When the filaments are textured, there is an increase in loft and therefore some amount of insulation. Polyester staple fiber is crimped and this does provide greater insulation in the yarns and fabrics. But a fabric of polyester spun yarn would not be as warm as a fabric made of the acrylics, silk, or wool; it would be warmer than if made of cotton, linen, or rayon. One of the reasons for the apparent greater warmth of polyester is its low absorbency. However, polyester crimped fiberfill or hollow staple variants can provide bulk and insulative properties.

Absorbency. Polyester is one of the least absorbent fibers. This low absorbency has two important advantages. Polyester fabrics will dry very rapidly since almost all the moisture will lie on the surface rather than penetrate the yarns. Fabrics of polyester fiber are therefore well suited for water-repellent purposes, such as rainwear. Furthermore, this low absorbency means that polyester fabrics will not stain easily. Many substances that would stain other fabrics lie on the surface and can be wiped or washed off easily. (One limitation, though, is polyester's affinity for oil, which stains and is extremely difficult to remove.) References to stain-repellent and soil-release finishes have been made on page 385.

Fabrics of low absorbency generally have the disadvantage of being clammy and uncomfortable in humid weather because they will not absorb perspiration or atmospheric moisture. As a result, an absorbent fiber such as cotton is often blended with the polyester staple.

Cleanliness and Washability. Since polyester fibers generally are smooth and have a very low absorbency, many stains lie on the surface and can easily be washed by hand or machine. Strong soaps are not needed. However, oil stains are more stubborn and under certain circumstances cannot be entirely removed. Some polyester fibers, such as Spectran, have built-in superior stain release and less redeposition of soil during laundering.

Fabrics of polyester filament yarn dry very quickly. Those of spun yarn dry comparatively rapidly if wrung out well. There is essentially no water shrinkage of polyester fabrics; therefore, shirts, blouses, and even slacks made entirely of polyester (including the sewing thread) may be safely laundered.

When ironing polyester fabrics, it is best to use low to medium heat. Excessive heat will cause polyester to melt. (Burning tobacco will quickly melt holes in such fabrics. Certain resins are being used to coat the material, thus minimizing this danger.) Actually, little ironing is needed even after long wear or after being completely wet, because garments made of polyester hold their shape and creases after being heat-set. Furthermore, the wrinkle resistance of polyester is extremely good.

Fabrics of spun polyester yarn that have a tendency to pill should be washed gently and brushed with a soft brush while drying in order to disentangle the fiber ends and straighten them out. Since PCDT polyester is, in general, weaker than PET polyesters, Kodel 200 fiber ends in spun yarns tend to break off rather than hold the pilling. Fabrics of Kodel 200 spun yarns therefore do not have as much pilling.

Effect of Bleaches. Fabrics of polyester may be safely bleached because polyester has good resistance to deterioration by household bleaches. If the polyester has an optical brightener, no bleaching is necessary.

Shrinkage. As has been indicated, polyester fabrics shrink as much as 20 percent during wet-finishing operations and they are generally heat-set in later treatments. Consequently, finished polyester woven and knitted fabrics will not shrink. They have excellent dimensional stability.

Fabrics of polyester blends should be properly treated for permanent press so as to prevent the nonpolyester component from shrinking. Also, garments should be sewn with polyester thread to avoid puckering.

Effect of Heat. Depending upon the type, polyester will get sticky at 440 to

468°F (227–242°C). Therefore, if ironing is needed, it should be done at lower temperatures such as those used for ironing rayon. At temperatures in the range of 480 to 554°F (249–290°C), polyester will melt and flame but will self-extinguish when heat or flame is removed unless the fabric has a finish which burns or supports combustion. Since sparks, burning cigarette ashes, and the like will easily melt holes in polyester fabrics, appropriate care should be exercised. However, flame-retardant variants are available (see Figure 22-5).

Effect of Light. Polyester has good resistance to degradation by sunlight. Fabrics of polyester are therefore well suited for outdoor use. Over a prolonged period of exposure to direct sunlight, however, there will be a gradual deterioration of the polyester fiber. When exposed to sunlight behind glass, polyester shows a considerable increase in resistance to sunlight; it has a marked superiority over most other fibers under these conditions and is therefore very well suited for curtains.

Resistance to Mildew. Polyester fabrics are absolutely resistant to mildew. They will not be stained or weakened. Should mildew form on the fabric, it would be due to the finish; but mildew should readily wash off the fabric without any deterioration to it. However, there may be some discoloration.

Resistance to Insects. Polyester is unaffected by moths, carpet beetles, silverfish, or other insects.

Reaction to Alkalies. At room temperature, polyester has good resistance to weak alkalies and fair resistance to strong alkalies. This resistance is reduced with increased temperature. At boiling temperatures, it has poor resistance to weak alkalies and dissolves in strong alkalies.

Figure 22-5 This infant's sleepwear is knitted of flame-retardant polyester fiber. *(Courtesy Michael Heron/Woodfin Camp & Assoc.)*

Reaction to Acids. Depending upon the type, polyester has excellent-to-good resistance to mineral and organic acids. Highly concentrated solutions of a mineral acid, such as sulfuric acid, at relatively high temperatures will result in degradation.

Affinity for Dyes. Polyesters can be dyed with appropriate disperse, azoic, and developed dyes at high temperatures, producing a good range of shades that have good-to-excellent washfastness and fair-to-good lightfastness. Some polyesters are modified to take basic (cationic) dyes. Solvent dispersion-dye techniques using ammonia or hydrocarbon solvents, such as perchlorethylene, may enhance dye reactions. Pigment colors have a tendency to crock and rub off.

Resistance to Perspiration. Polyester has no significant loss of strength from continued contact with either acid or alkaline perspiration.

POLYESTER FIBER BLENDS

Polyester fiber has been successfully blended with many other fibers. Various effects and combinations of properties are derived from these blends depending on the fibers used and on the percentages in the blends. One of the most important characteristics that polyester provides is its high degree of shape retention for garments that require little or no ironing after they are washed (see Figure 22-6).

Polyester and Cotton

For satisfactory wash and wear purposes, fabrics for rainwear, tailored clothing, dress shirts, and sport shirts usually have a blend of at least 65 percent polyester with the cotton. Polyester will provide wrinkle resistance and shape retention. Cotton

Figure 22-6 Polyester blends well with a variety of fibers; it promotes excellent shape retention. Shown here are (a) sweater knitted of a 70/30 polyester and nylon blend. (b) Shirts and shorts of 50/50 polyester and cotton blend. *(Courtesy Hoechst Fibers Industries)*

will provide absorbency and consequent comfort. However, unless properly constructed and properly cared for, a fabric of a polyester and cotton blend may pucker and lose its shape if the cotton should shrink or if cotton thread is used in sewing. Polyester and cotton blends are well suited for fabrics to be given a permanent press resin finish. The polyester not only contributes its own inherent shape-retentive qualities but also retains its strength, thereby reducing the total potential strength loss from resin finishing that an all-cotton fabric would have.

Where greater absorbency and softer hand are desired, a 50/50 blend is preferable, but there will be a corresponding strength loss of as much as 20 percent as well as a slight loss in resilience. A 50/50 blend of polyester and cotton is also satisfactory for effective permanent press finishes.

On the other hand, blends of as much as 80/20 of polyester and cotton, respectively, will have a somewhat stiffer, slicker hand. Strength, wrinkle resistance, and shape retention will be increased but absorbency will be reduced.

Polyester and Wool

In combination with wool, polyester provides outstanding wrinkle resistance and crease retention, so that wet or dry, the shape retention is improved according to the proportions used. The greater abrasion resistance of polyester also provides longer wear. The wool contributes good draping quality and elasticity. The wool also reduces the hazard of melted holes due to burning tobacco. The greater the proportion of wool, the less pilling there is likely to be.

Blends of polyester and wool generally range from 65 percent polyester and 35 percent wool to 60/40, 55/45, and 50/50, respectively. For lightweight, shape-retentive summer suiting, 65 percent polyester and 35 percent wool is a satisfactory blend. For optimum benefits of both fibers, a 60/40 blend of polyester and wool, respectively, appears to be generally best for medium worsteds. A blend of 55 percent polyester and 45 percent wool is suitable for year-round garments. Where greater warmth is desired, a 50/50 blend for woolens is preferable.

Polyester and Rayon

In a blend with viscose rayon, polyester gives greater resiliency, shape retention, and durability. Viscose rayon provides absorbency and variety of color and texture. For satisfactory wash and wear service, a blend of at least 55 percent polyester with the rayon is desirable. Variations with other rayon variants are possible. For example, a 50/50 blend of polyester and a viscose rayon variant like the hollow Fibro HSO (see page 323) will provide greater absorbency, body, and drape than a similar blend of polyester with either regular viscose or cotton.

A blend of 65 percent polyester and 35 percent high wet-modulus rayon provides a strong, durable, and serviceable fabric. The fabric has a good hand and drapes well. The rayon again provides the absorbency that polyester lacks. The strength and durability of such blends are comparable with blends of polyester and Pima cotton and have the advantage of greater resilience and shape retention.

Polyester and Triacetate

Since both fibers are thermoplastic, fabrics made of polyester and triacetate will

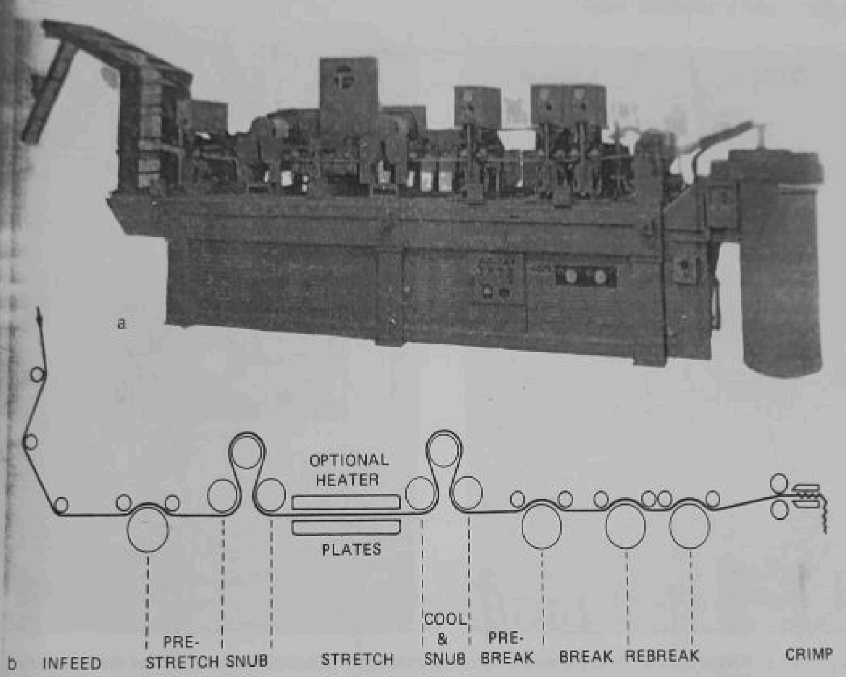


Figure 22-2 (*a*) Polyester tow bands of up to 1,000,000 denier are broken by stretching and restretching the broken tow to reduce the staple to desired relatively uniform length, then crimped and formed into staple sliver. (*b*) The flow diagram depicts the process. (*Courtesy Turbo Machine Co.*)

Semidull, regular tenacity polyester may also be spun on the worsted or rayon (modified cotton) system. These yarns are used for winter-weight and spring-weight fabrics. Such fabrics include finished worsteds like sharkskin, gabardine, and Bedford cord, as well as such napped unfinished worsteds as flannel and serge. Still heavier weights may be made of bright, regular tenacity fiber and spun on a woolen or modified worsted system for pile fabrics.

Regular tenacity polyester staple containing an optical brightener may be spun into yarn for such products as men's knitted underwear. Mid-tenacity polyester is very suitable for blending with cotton and high wet-modulus rayon fibers for spun yarn for such purposes as men's shirting fabrics.

Bright, trilateral, polished staple may be spun into yarn to be used to make carpets or upholstery fabrics. Trilateral, polished, basic-dyeable staple is also available for such purposes as upholstery fabrics.

A variety of staple polyesters called conductive epitropics has also been developed. These polyesters contain tiny particles of carbon powder embedded in the surface of the fiber. The carbon particles give the fiber the ability to conduct electricity, which provides antistatic protecple lengths. The yarns are produced, basically as monofilament, multifilament, and spun (see Figure 22-1).

Filament Yarns

Filament yarns are produced of PET polyester. They are made in monofilament and multifilament forms. The direction and amount of twist are determined by the desired end use. The variety of characteristics of the yarns is also predetermined.

Bright, regular tenacity polyester yarn is one popular type. It has good light resistance, as well as stretch and sag resistance. It can be used for sheer, lightweight fabrics, such as tulle, voile, and organdy, and is very suitable for curtains. Another very popular type is the regular tenacity, semidull yarn. It is used for a wide variety of apparel, including dresses and lingerie. A duller version is used for shirts and blouses.

Another type produced is a semidull polyester containing an additive that gives it an affinity for basic dyes, thereby giving the yarn greater versatility for use in fabrics that can be cross-dyed. Sometimes the PET polyester is treated with an optical brightener so that the fabric made of this type of yarn will have a permanent white character. To impart more drapability, softer hand, and greater luster, the yarn may be made of filaments that are trilateral, or trilobal. Polyester yarns, which are resistant to various chemicals, seawater, and microorganisms, are made of a bright, high-tenacity fiber for such industrial uses as conveyor belts, ropes, netting, and sails. High-tenacity polyester filament yarns are available for tire cord.

Textured Yarns

Textured polyester yarns are produced of [illegible] They are given a

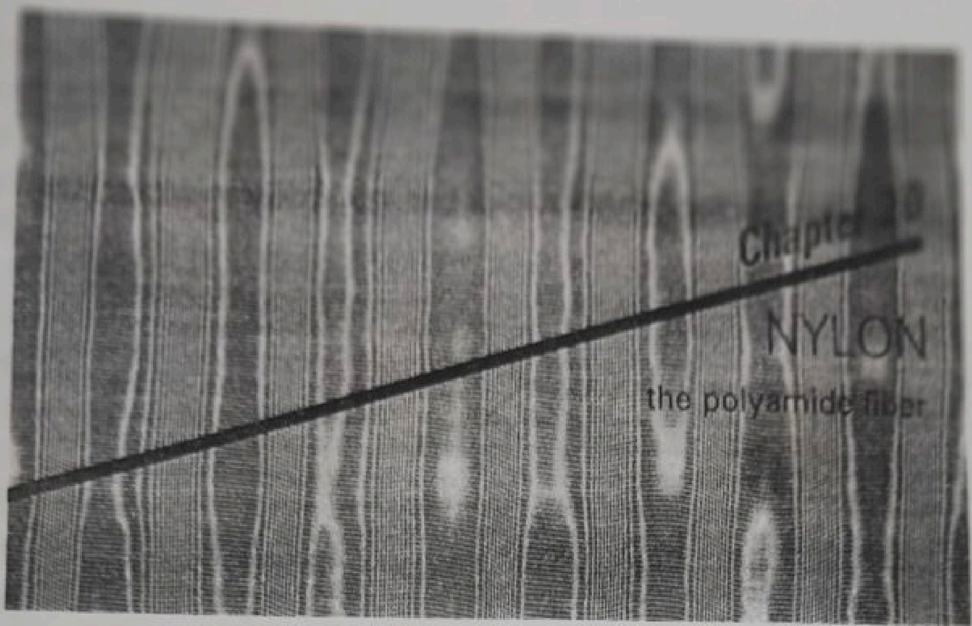
texturizing either in connection with the drawing process or subsequently as part of the throwing and texturizing process in producing the finished yarns. [illegible] polyester fiber is one example (see pages 65–66).

Spun Yarns

Spun yarns are made of staple or of cut, crimped tow of either PET or PCDT polyester fiber (see Figure 22-2). The staple is produced in a wide range of deniers and lengths according to the desired end uses. The staple may be bright, semidull, or dull. The fiber may be polished to reduce the crimp and increase the luster. It may be regular-, mid-, or high-tenacity. It may be round or trilateral for increased sheen. The staple may be spun directly into yarn or blended with other staple, such as cotton, wool, or rayon, and then spun into yarn.

The type of fiber cut into staple depends upon the ultimate end use. PCDT (Kodel 200 series) polyester fiber is particularly suited to staple and spun yarn purposes. It has great resilience, exceptional bulking ability, and good resistance to pilling. Unless the product is labeled as being made of this type of polyester, the consumer should assume that PET polyester is used and must rely upon the proper choice of fiber and/or yarn made by the product manufacturer.

Semidull, regular-tenacity polyester staple may be spun on either the cotton or wool system, depending upon the ultimate yarn desired. Finer yarns are used for summer suitings that require both unusual resiliency and dimensional stability to prevent puckering and change in shape during humid weather. Heavier yarns made of this staple may be used for outerwear and for knitted fabrics because of their exceptional shape retention and stretch resistance.



The word "nylon" is a generic term that designates a group of related chemical compounds classified as *polyamides*. Nylon is not a trademark—it is a textile, just as cotton, linen, wool, silk, rayon, and acetate are textiles. As defined by the Federal Trade Commission (FTC), nylon "is a long-chain synthetic polyamide in which less than 85 percent of the amide linkages are attached to two aromatic rings." While this chemical definition may not be easily recognized by laypersons, it is evident that variations are possible and that there could be and are many varieties of nylon with certain differing properties.

HISTORY OF NYLON

Responsibility for the discovery or invention of nylon belongs to E. I. du Pont de Nemours & Co. More specifically, the credit belongs to Dr. Wallace H. Carothers and his staff of organic chemists of that company's chemical department. Realizing that there was a need for a more active program of research to provide new developments that would insure the future growth of the company, Du Pont began a long-range program of chemical exploration in 1928. Deviating from the applied research previously conducted, this fundamental research aimed primarily to develop basic knowledge of chemical materials and processes. Dr. Carothers was interested in obtaining a better understanding of polymerization. He wanted to know how and why certain molecules join to form "giant" molecules, such as those that occur in cotton, silk, and rubber. After many months of research, one of Dr. Carothers's assistants discovered that one polymer, which looked like clear, heavy molasses when molten, could be drawn out into a long fiber. When it cooled, the fiber could be drawn out farther to several times its original length. This strand was strong, lustrous, and silky. The question naturally arose as to whether this would make a good textile fiber.

At this point, the experiments became practical. The Carothers group was working with a type of compound called *polyesters*. A great many were synthesized. Each was deficient in one or more vital textile properties. Attempting to find a better fiber, they mixed polyesters and polyamides, which are related to polyesters. They were not successful and therefore decided to discontinue the mixtures and concentrate on the polyamides. One of the chemists filled a container, fitted with the tip of a hypodermic needle, with a hot viscous polyamide solution. He squirted a stream of it into the air, and the stream cooled into a fine filament. After the lustrous fiber was drawn and tested, it was found to be strong and pliable and had such promise, that a large group of chemists and engineers were employed to make it a commercial success. During the next several years, research with a series of polyamides continued. In February, 1935, one of these was made from hexamethylene diamine and adipic acid. This polymer was called 6,6 because each of these component chemical compounds contains six carbon atoms per molecule. This 6,6 polymer proved to be best at that time.

The name "nylon" was given to this material. (The name has no meaning. It was chosen because it was short, catchy, and hard to mispronounce.) The discovery was made public in 1938. Since nylon is proteinlike in composition, the fiber was said to be similar in certain of its properties to silk, wool, and hair. Furthermore, this new fiber had many wonderful properties of its own. On May 15, 1940, nylon hosiery went on sale throughout the country. After that, nylon began to be used for a wide variety of garments. Du Pont subsequently licensed other companies to use its patents to produce nylon 6,6, and later variations in techniques were independently patented by others to produce this nylon.

Other experimentation with polyamides eventually led to the creation of other forms of nylon. In 1939 Schlak and Kleine of the I. G. Farben combine produced a German counterpart, nylon 6, from a polyamide called *caprolactum*, which contains 6 carbon atoms. Since then, other forms have been developed: examples are nylon 7 produced in the U.S.S.R., nylon 11 produced in Italy, and nylon 4, 8, 10, 6,10, and 6,12 produced in the United States. These nylons are all polyamides created from various raw materials in different ways, as found most economical by the producer. Chemically, they are similar but differ in molecular structure, which sometimes results in subtle differences in properties. Today, the major production in the United States is nylon 6,6 with less production of nylon 6, used primarily for carpeting and industrial fabrics. The major type produced in foreign countries is nylon 6.

METHODS OF MANUFACTURE

Nylon is actually a group of related chemical compounds. It is composed of hydrogen, nitrogen, oxygen, and carbon in controlled proportions and structural arrangments. Variations can result in types of nylon plastics, such as combs, brushes, and gears. We are here concerned with the production of nylon yarn. Since the two types of nylon that predominate the market are nylon 6,6 and nylon 6, we shall consider their basic methods of production, although variations in technique do exist among manufacturers (see Figures 20-1 and 20-2).

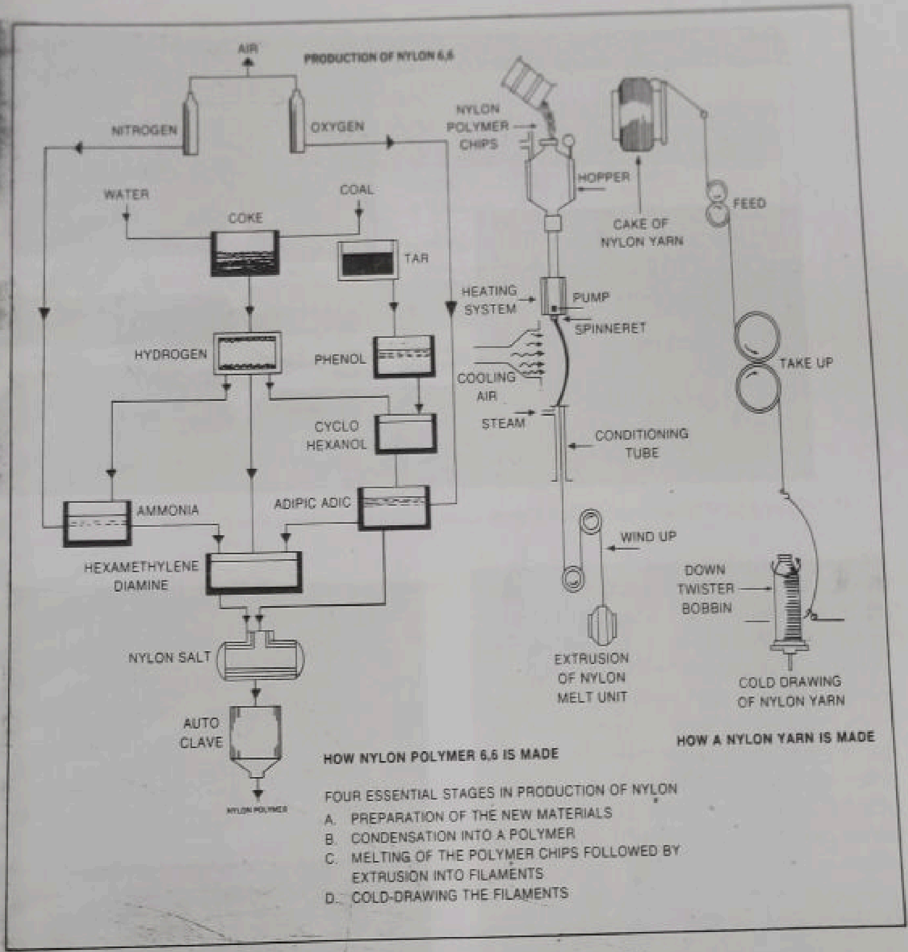


Figure 20-1 How nylon 6,6 is made. *(Courtesy Celanese Fibers Marketing Co.)*

Nylon 6,6 Synthesis

By a series of chemical steps beginning with such raw materials as coal, petroleum, or such cereal byproducts as oat hulls or corncobs, two chemicals called *hexamethylene diamine* and *adipic acid* are made. These are combined to form nylon salt. Then, since the nylon salt is to be shipped to the spinning mill, it is dissolved in water for easy handling. At the spinning mill, it is heated in large evaporators until a concentrated solution is obtained. The concentrated nylon salt solution is then transferred to an autoclave, which is like a huge pressure cooker. The heat combines the molecules of the two

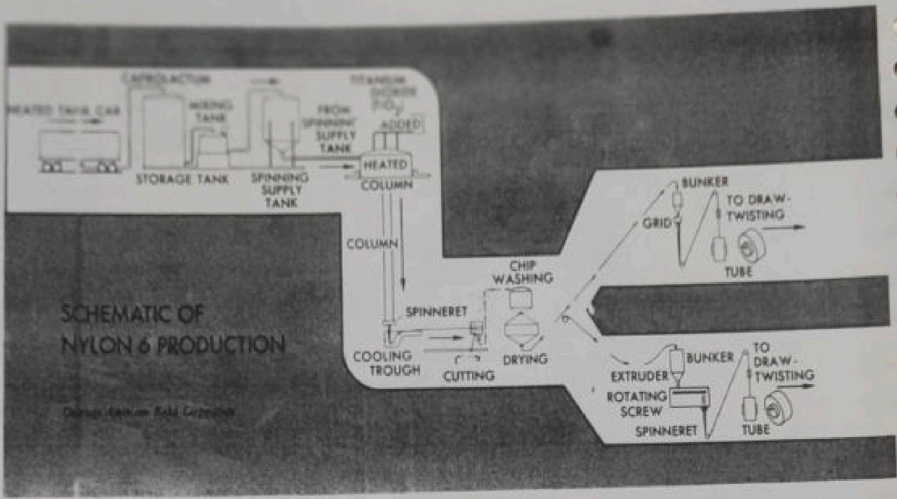


Figure 20-2 Schematic of nylon 6 production. *(Courtesy American Enka Co.)*

chemicals into giant chainlike ones, called *linear superpolymers*. This process gives nylon a molecular structure somewhat like wool and silk and is also the source of nylon's strength and elasticity. The linear superpolymer is then allowed to flow out of a slot in the autoclave onto a slowly revolving casting wheel. As the ribbons of molten nylon resin are deposited on the wheel, they are sprayed with cold water, which hardens them to milky white opaque ribbons. The ribbons are removed from the casting wheel to a chipper, which transforms them into flakes (see Figure 20-3).

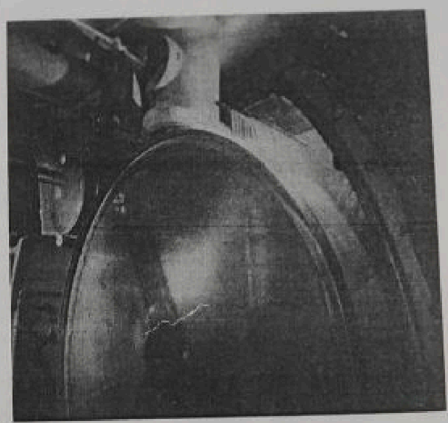
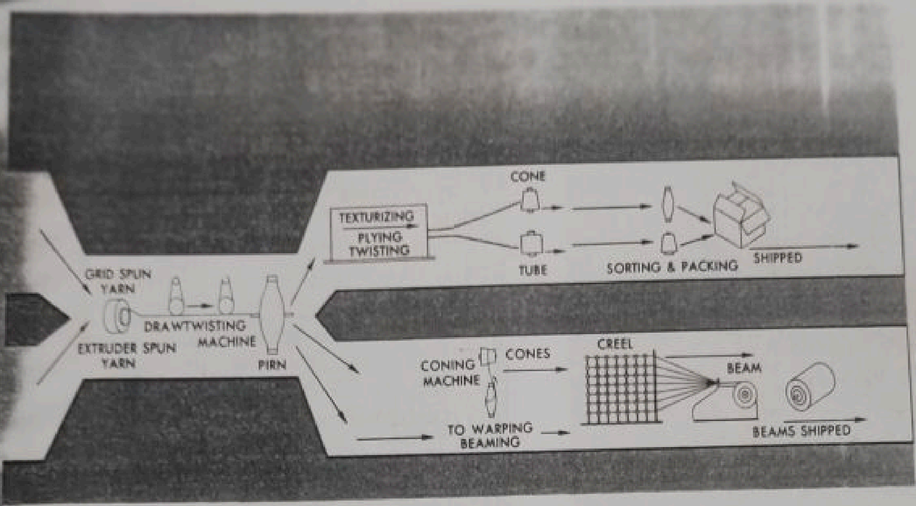


Figure 20-3 Nylon polymer, pressed out on this huge casting wheel, is sprayed with water and solidified into a strip resembling ivory. *(Courtesy E. I. du Pont de Nemours & Co.)*

Nylon 6 Synthesis

Beginning with coal, a series of chemical steps produces another complicated chemical called *cyclohexanone-oxime*, which converts to a substance called *caprolactum* when it is treated with sulfuric acid. Polymerization of the molten caprolactum is begun by gently heating it in a steam-jacketed stainless steel vessel as it is constantly mixed. It is then filtered and pumped to a polymerization kettle where, under carefully controlled steam heat and pressure, the caprolactum is stabilized as a



superpolymer (Figure 20-4). The molten nylon 6 polymer is then converted into chips in a manner similar to that of nylon 6,6.

Spinning the Fiber

Nylon fiber can be made in several ways. The most important of these methods is the *melt process* that, depending upon the denier (or decitex) of the filament desired, generally uses either the grid or extruder spinning technique. In grid spinning, nylon flakes from several autoclaves are blended and poured into the hopper of the spinning machine to insure uniformity in the final nylon yarn. Through a valve in the bottom of the hopper, the nylon flakes fall onto a hot grid, which melts them. The molten nylon is pumped through a sand filter to the spinneret, a disk about the size of a silver dollar. The spinneret has one or more holes, depending on the purpose for which the yarn is to be made. As the filaments

Figure 20-4 Polymerization of the molten caprolactum under controlled steam heat and pressure produces the stabilized superpolymer, nylon 6. (*Courtesy American Enka Co.*)

come out of the spinneret and hit the air, they solidify. After they cool, the filaments converge, pass through a conditioner where they are moistened sufficiently to make them adhere together, and are given a few turns per inch (centimeter) to form a single thread and facilitate further handling.

Extruder spinning is primarily used for heavier yarns. The chips flow by gravity into a device that forces them by screw action through heated zones. The combined action of the heat and screw pressure melts the chips. The molten liquid is subsequently processed in the same manner as described for grid-spun yarn.

Variations in the ultimate appearance of the nylon filaments may be accomplished. It is possible to obtain a bright, lustrous nylon that can be used for satin or a semidull or dull nylon for curtains. Nylon may be delustered by a process similar to delustering rayon and acetate. The delusterants are titanium oxide, barium sulfate, zinc oxide, or zinc sulfate. When any of these chemical compounds are mixed with the polyamide solution, they will cause the nylon to be delustered. Although nylon is naturally white, the whiteness can be increased by adding an optical whitener to the molten polymer.

The nylon filaments are usually spun from round holes and have a round cross section; such fibers are smooth and slippery. The appearance and texture of the nylon filament can be altered by adjusting the shape of the holes of the spinneret. Nylon filaments may be spun to have a trilobal cross section. Antron, a nylon 6,6 fiber, and Enkaloft, a nylon 6 fiber, are of this form. They have a unique luster, a dry, pleasing hand, greater opacity, and can be printed with a sharper definition and clarity. Antron III nylon 6,6 and Enkalure II nylon 6 are forms of soil-hiding nylon fibers. Although they will hide soil, they will nevertheless get dirty. Their somewhat elongated trilobal very smooth surfaces highly reflect light in such a way that sheen overcomes the darkened (dirty) areas. These yarns are crimped for appropriate applications, such as carpets.

Nylon multifilaments, such as Antron III and Enkalure II can also be produced so that they develop a permanent crimp. Crepeset is a 20-denier monofilament nylon 6 fiber that is permanently crimped. As the trademark implies, the fiber is extremely well suited for producing crepe fabrics that do not require a high twist. Such fabrics not only have a crepe appearance but, in addition, have a soft, luxurious texture not usually associated with crepes.

Nylon filaments, such as Ultron may be produced as *epitropics* or *conductive epitropics*. They contain minute particles of carbon powder embedded in their surfaces, thereby providing the ability to conduct electricity. Excellent antistatic properties can thus be produced in multifilament yarn with an extremely small amount of the carbon particles in a relatively few filaments of such yarn.

High-tenacity nylon has been developed for tires, seat belts, cordage, and industrial fabrics. There are several types produced for such specific purposes.

Drawing the Fiber

Up to this point, the chemical structure of the filaments is about the same as the flakes from which they were made. The filaments are opaque, have poor pliability, and are not very strong because of the random arrangement of the linear superpolymer molecules. This can be changed, however, by stretching, or cold-drawing the filaments from two to seven times their original length. The amount of stretching is dependent on the diameter, elasticity, and strength desired. As the filaments are stretched, they become more and more transparent. The polyamide molecules straighten out, become parallelized, and are brought very close together. Up to a point, the nylon becomes stronger, more elastic, more flexible, and more pliable.

This elongation by cold-drawing, which is permanent, is accomplished by unwinding the yarn from one godet, or wheel, and winding it onto another godet that is rotating much faster. The speed of the second wheel determines the amount of cold-drawing; that is, if the nylon filament is to be stretched four times its original length, it is unwound from one godet and wound on another at a speed that will subject it to a fourfold stretch during the operation.

The yarn from the second godet is wrapped on a cylindrical tube called a *pirn*. A small amount of twist is normally inserted in the yarn as it is wound on the pirn so as to keep the filaments together and aid in the future processing of the yarn (see Figure 20-5).

In conjunction with the drawing process, the nylon filaments may be textured. Draw-texturing at the production stage places this important process under the control of the fiber producer and eliminates the additional subsequent step of texturizing by the yarn producers.

TYPES OF NYLON YARN

The diameter of the individual nylon filaments is determined by the rate of delivery from the pump to the spinneret, by the number of holes in the spinneret, and by the rate at which the yarn is drawn away

Figure 20-5 Winding pirns of nylon filament for shipment. *(Courtesy E. I. du Pont de Nemours & Co.)*

from the spinneret. The denier, or size, of the yarn before drawing is determined by the diameter and number of filaments in the yarn. The size of the yarn after drawing is determined by its original diameter and the amount of cold-drawing. If it is drawn three times its original length, the stretched yarn will be one-third of its original diameter. The individual filaments produced usually range from 1 to 15 denier (1–17 dtex).

Monofilament Yarns

Though single-filament, or monifilament, yarns of 7 denier (8 dtex) are produced, 12-denier (13 dtex), 15-denier (17 dtex), or heavier yarns are more often manufactured. The monofilament yarns are used for hosiery and for industrial filters. These yarns are very fine and have little or no twist. Consequently, they are relatively weak nylon yarns. Heavier and stronger monofilament yarns are also produced for various purposes.

In 1963 Du Pont introduced a new type of nylon monofilament yarn for hosiery under the trademark of Cantrece. It is a bicomponent fiber created by extruding nylon 6,6 and 6,10 solutions from a single spinneret to form the filaments adhering as one. It is a self-crimping yarn. Upon exposure to steam heat, Cantrece nylon develops a helical, or corkscrew, shape as a result of the different effects of the heat on the components of the fiber. The amount of crimp is dependent upon the temperature and rate of heating. The crimp provides greater resilience and superior fit as well as fit retention and comfort. The improved fit characteristic is said to increase the life of the hose, since there is less strain on the yarn.

Multifilament Yarns

Multifilament yarns are made in both standard and high-tenacity forms. The number of filaments in each yarn varies according to the purpose of the yarn. The yarns generally range in denier from 20 to 210 (22–233 dtex). Multifilament yarns are stronger than monofilament yarns because of the numerous filaments. The strength can be further increased by the amount of twist given to the yarns.

Stretch Yarns

Nylon filaments can be processed to have a crimp or coiled characteristic. This gives yarns made of such nylon filaments the ability to be greatly stretched (like a spring) and come back to shape when the tension is released. These yarns are produced under several trademarks, of which one of the better known is Helanca. (See pages 53–61.)

Textured Yarns

Nylon filaments can also be processed to have a looped characteristic. Crimp-textured nylon is sometimes referred to as BCF nylon—that is, bulk continuous filament nylon. It is given a permanent crimp by the producer. Thrown yarns of these filaments have a texture and hand similar to yarns made of a staple fiber, such as cotton, but retain all the other characteristics of filament yarns. One of the best known of these textured yarns is Taslan, discussed on pages 65–66, which is used for sport shirts and similar apparel. Some textured filament yarns have a curly appearance that imparts a resilient, springy effect called *loft*. Examples of these are Cumuloft and Enkaloft, which are used for rugs (see Figure 20-6).

Spun Yarns

Nylon filaments may be cut about 1 to 5 inches (25–125 mm) in staple length. The individual filaments range in denier from 1.5 to 15 (1.7–17 dtex). The staple is usually crimped and spun on a cotton system. These yarns are fuzzy and soft. They have lower tensile strength but greater abrasion resistance. They are not so elastic as the filament yarns and take longer to dry.

TRADEMARKS OF NYLON FIBERS

To identify and promote their respective products, manufacturers give trademarks to their nylon yarns that are found in advertisements and on labels or tags attached to garments and fabrics. Although the basic properties of these nylon yarns are similar, it is apparent that the

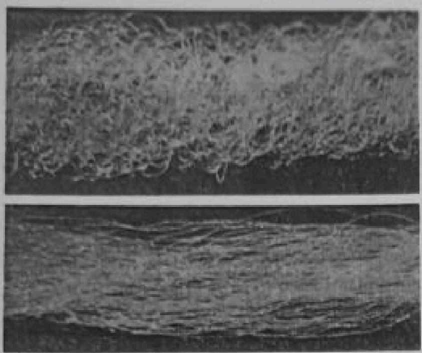


Figure 20-6 Close-up of untextured nylon filament yarn (bottom) and Cumuloft textured nylon filament yarn (top) showing the latter's curly, bulky appearance. *(Courtesy Monsanto Textiles Co.)*

characteristics of these yarns differ insofar as the type of nylon, cross section of the fiber, and yarn construction are concerned (see Table 20-1).

FINISHING NYLON FABRICS

Nylon fabrics can be given various finishes:

Antistatic finish—for reduction of electrostatic buildup

Embossing—for pattern or design

Heat setting—for permanent shape

Moiréing—for shimmer effect

Molding—for shaping fabrics

Nylonizing—for increased absorbency

Water repellency—for added protection against water

An outstanding feature of nylon is that it is thermoplastic; consequently, a nylon fabric or garment can be heat-set by subjecting it to a high degree of heat while being held in a particular shape. After being heat-set, the fabric or garment will always retain its shape, creases, or pleats, and require little or no ironing. Washing, dry cleaning, or wear will not cause loss of shape. Properly done, heat-setting prevents nylon fabrics from shrinking.

Since nylon is thermoplastic, the application of a hot embossing roller will cause the nylon to melt in conformity with the embossing pattern. This results in a permanent finish that cannot be removed by wearing, washing, or dry cleaning. The same principle applies to nylon moiré. As with thermoplastic acetate, nylon moiré is permanent.

Because nylon is thermoplastic, fabrics made of nylon may also be *thermoformable*, which means that they can be molded into shapes by the application of pressure and heat. The fabrics may have a woven, knitted, or lace construction that has been only partially drawn in the manufacturing process. When such a fabric is preheated and then pressed in a heated mold, the drawing operation is, in effect, completed and the fabric is heat-set to the desired permanent shape. Examples of such products are hats, brassieres, and swimsuits.

Raised designs may also be created on nylon fabrics by printing the background area with phenol, which causes the treated nylon to shrink and the untreated areas to pucker.

Nylon is not very absorbent, which is a disadvantage for shirts and lingerie. To overcome this, nylon fabrics may be treated by a process known as Nylonizing. The technique utilizes nylon 8, which is more absorbent than other forms of nylon, to coat other nylon fabrics for improved absorbency.

Nylon fabrics may also be treated with a water-repellent finish, which makes them ideal for rainwear and for shower curtains.

EVALUATING NYLON FABRICS

Because nylon fabrics are produced in such a wide variety, they can be made to appear similar to cotton batiste and plissé, to the texture of linen, to jersey for sweaters, and to silk, rayon, or acetate shantung and velvet. Nylon (and to a lesser extent, polyester and acrylic) has superseded wool for rugs and carpets. The properties of these fabrics depend on the type of nylon, the cross section of fiber, whether the fabric is made of multifilament or spun yarn, and how the fabric is constructed.

Although there are basic properties that all nylons share, the consumer should maintain an awareness of their variations when selecting or caring for nylon fabrics.

Strength. Nylon is produced in both regular and high-tenacity strengths. Although one of the lightest textile fibers, it is also one of the strongest. It is surpassed in strength only by aramid and glass. Its strength competes with high-tenacity viscose rayon as well as with polyester fibers.

The strength of nylon will not deteriorate with age. These advantages make nylon desirable for sheer hosiery, curtains, blouses, dress fabrics, upholstery and carpets. Nylon not only has great tensile strength with light weight, it is also tough and pliable. Nylon has the highest resistance to abrasion of any fiber. It can take a tremendous amount of rubbing, scraping, bending, and twisting without breaking down. Spun nylon yarn has even a higher abrasion resistance than filament nylon, which makes it desirable for socks and upholstery.

Elasticity. Nylon is one of the most elastic fibers that exists today, though it does not have the exceptional elastic quality of spandex fibers. After being stretched, nylon has a strong natural tendency to return to its original shape. Like any other textile, nylon has its own limit of elasticity. If stretched too much, it will not completely recover its shape. In addition, the type of yarn and the construction of the fabric may contribute to the behavior of the garment. For example, spun nylon is not so elastic as filament nylon. Knitted spun nylon fabrics, such as those used in sweaters, will sag more easily than knitted filament nylon fabrics, such as those used in tricot.

Of course, such stretch nylon yarns as Helanca and Agilon (discussed on pages 55–61) have exceptional elasticity. These yarns have given rise to a wide variety of stretch garments that retain their shape and comfortably conform to the contours of the body.

Resilience. Nylon has excellent resilience. Nylon fabrics retain their smooth appearance, and wrinkles from the usual daily activities fall out readily. Pile fabrics, such as velvets and carpets, keep a neat uncrushed appearance.

Drapability. Fabrics of nylon filament yarn have excellent draping qualities (see Figure 20-7). Lightweight sheers may have a flowing quality, medium-weight dress fabrics can drape very nicely, and heavier-weight Jacquards also drape well.

Heat Conductivity. Nylon fabrics may or may not conduct heat well. The warmth or coolness of a nylon garment depends on the weave of the fabric and on the type of yarn used. The smoothness, roundness, and fineness of nylon filaments permit the manufacture of very smooth, very fine yarns, which can be packed very closely when weaving the fab-

Figure 20-7 Because of its excellent draping qualities nylon is suitable for flowing clothes of many styles. *(Courtesy E. I. du Pont de Nemours & Co.)*

ric. If nylon fabric is woven compactly, it will not be porous. The tight construction will not permit air to circulate through the fabric, and the heat and moisture of the body will not readily pass through it but will build up between the fabric and the body; so, the wearer will feel very warm. Such fabrics are good for winter apparel, such as windbreakers, but are not suitable for summer garments.

On the other hand, these fine nylon filament yarns may be woven into extremely thin, lightweight, sheer fabrics. These materials are very porous and permit the circulation of air. Consequently, they are cool and can be used for summer blouses and curtains.

Spun nylon yarn will produce warm fabrics. These yarns are composed of thousands of short, crimped fibers twisted together, which provide millions of tiny dead-air spaces that act as insulators. This insulation makes spun nylon fabrics warm.

Absorbency. Nylon does not absorb much moisture. Fabrics made of nylon filament yarns will not readily wet through the material—most of the water remains on the surface and runs off the smooth fabric, which therefore dries quickly. Such fabrics are useful for raincoats and shower curtains. Spun nylon fabrics, however, will not dry quickly. Droplets of water tend to cling to the sides of the thousands of staple fibers, clogging the air spaces and relatively increasing the drying time for spun nylon fabrics. Nylon's low absorbency has a disadvantage in that the fabric feels clammy and uncomfortable in warm, humid weather. (Nylon 4 and nylon 8 varieties have moisture-absorption properties similar to cotton. However, due to other factors, little is produced.) Sometimes a hydrophilic (water-attracting) or a Nylonizing finish (see page 189) is used on nylon 6 or 6,6 fabrics.

Cleanliness and Washability. Because of nylon's smooth surface, dirt and stains often come clean merely by using a damp cloth. If the yarn has an antistatic component in it or if the fabric has an antistatic finish, then dirt particles are less likely to be attracted and cling, and the garment will stay cleaner longer. Otherwise, an antistatic additive could be used in the washing or in the drying machine. To wash nylon garments by hand or washing machine, use lukewarm water at about 100°F (38°C) and a detergent or soap with a water softener.

White nylon fabrics should always be

separated from colored fabrics before washing because the nylon will pick up color (even from the palest pastels) and develop a dingy gray appearance that is extremely difficult to remove. Garments should be thoroughly rinsed to obtain thorough removal of soil particles and drip-dried to obtain maximum freedom from wrinkling.

Nylon filament fabrics dry very quickly. They need little or no ironing because the garments are usually heatset to retain their shape, pleats, or creases.

Spun nylon has a tendency to pill, or form balls, on the surface of the fabric. To minimize this, such fabrics should not be rubbed. They should be washed gently, preferably by hand. Brushing with a soft brush will reduce the pilling.

Effect of Bleaches. With proper care, nylon fabrics retain their whiteness and should not need bleaching. However, if the nylon does become yellow or gray due to either the finish on the fabric or the absorption of color from other fabrics washed in the same water, a good, common household bleach may be used with reasonable care.

Shrinkage. Nylon has good dimensional stability and retains its shape after being wet.

Effect of Heat. Like acetate, nylon will melt if the iron is too hot; therefore, the iron should be set at the proper heat level. Special care must be taken with fabrics made of nylon 6 because it has a lower melting point at 420°F (216°C) than nylon 6,6 at 480°F (250°C). One can identify the type of nylon by its trademark, as shown in Table 20-1.

Effect of Light. Bright nylon is more resistant to the effects of sunlight than most other fibers. Dull nylon will deteriorate a little more quickly than bright nylon; however, even dull nylon has good resistance to light.

Resistance to Mildew. Mildew has absolutely no effect on nylon. Mildew may form on nylon, but it will not weaken the fabric.

Resistance to Insects. Moths and other insects will not attack nylon because it has no attraction for them.

Reaction to Alkalies. Nylon is substantially inert to alkalies.

Reaction to Acids. Nylon is decomposed by cold concentrated solutions of such mineral acids as hydrochloric, sulfuric, and nitric acids. A boiling dilute 5 percent solution of hydrochloric acid will destroy nylon.

Affinity for Dyes. Nylon 6 has greater affinity for dyes than nylon 6,6 and can be more easily dyed with a wider range of dyes. Both types of nylon retain their color and have good resistance to fading. Nylon 4 has excellent dyeability.

Resistance to Perspiration. Nylon fabrics are resistant to perspiration. The color, however, may be affected.

NYLON FIBER BLENDS

The consumer uses many textile products that do not possess all the properties that may be desired in a fiber. For example, one may prefer a coat with sufficient warmth but less weight; cool, light summer clothes that would not lose their fresh, clean appearance on hot sticky days; fabrics that would wash readily, dry quickly, and not lose their shape. Textile designers and engineers are producing new fabrics to meet such needs. These combine or blend two or more fibers to give the desired properties to the fabrics. We can consider here blends of nylon with other fibers thus far discussed.

Nylon and Cotton

When properly combined with cotton, nylon adds strength, which allows the development of unusually fine textures not possible to obtain from cotton alone. Nylon provides smoothness, silkiness, and dirt rejection. It also reduces the weight of the fabric and increases its wrinkle resistance. The cotton gives softness and moisture absorption. This combination permits the weaving of fabrics that are soft, supple, and extremely serviceable. If the combination is not properly balanced, the cotton may shrink, causing the fabric to pucker. Also, the nylon fibers may cut the cotton fibers. A blend of at least 17 percent high-tenacity nylon staple with cotton can make a very durable fabric.

Nylon and Wool

The proper combination of nylon and wool will produce a lighter-weight fabric with greater durability. Such a fabric will retain the hand, drape, body, absorbency, and warmth of wool as well as the elasticity, resilience, and shape retention of nylon. The properties of the fabric will be in direct proportion to the amount used of each of the two fibers. A blend of 10 to 15 percent nylon and the remainder wool is considered satisfactory.

Nylon and Silk

In this combination, the silk improves the hand and provides moisture absorption. The nylon improves the stability or shape retention, as well as the elasticity and strength.

Nylon and Rayon

In this blend, the nylon gives wrinkle resistance and strength. The rayon gives suppleness, drape, and moisture absorption. Such a combination makes possible a fine-quality fabric of extremely light weight. As with cotton, if the combination is not properly balanced, the rayon may shrink, causing the fabric to pucker. Also, an improper blend of nylon and rayon may result in the nylon fibers cutting the rayon fibers. Like cotton, rayon staple blended with high-tenacity nylon staple can produce fabrics with 70 percent longer wear than all-rayon fabrics if the nylon is blended in a proportion of at least 17 percent. This blend is desirable for garments classed wash and wear.

Nylon and Acetate

The acetate in such a blend provides a luxurious hand and the nylon gives light weight and strength. As with cotton or rayon, improper blending may result in the nylon cutting the acetate fiber, and in some fabrics puckering may occur. Also, neither nylon nor acetate absorbs much moisture. Such fabrics may feel clammy and uncomfortable in warm and humid atmospheres.

Nylon and Triacetate

A blend of 15 percent nylon and 85 percent triacetate in gabardines for shirts, slacks, and fabrics for outerwear is a satisfactory combination. The nylon provides strength to give good durability. Fabrics of this blend hold their creases and pleats and shape well. They can be laundered easily and need little or no ironing. Garments made of such a blend are among those classed as wash and wear type.

The formation of yarn from staple fibers by spinning becomes possible when they have surfaces capable of cohesiveness. This quality is exemplified by the natural twist of the cotton fibers which enables them to entwine around each other, the roughness of the linen fibers which cause them to cling together, and the scales on the surfaces of the wool fibers which cause them to grasp each other. (For a close-up examination of the fibers, see Chapter 33.) Flexibility permits the fibers to be twisted around one another. Uniformity of staple gives yarns a required evenness and improves the quality.

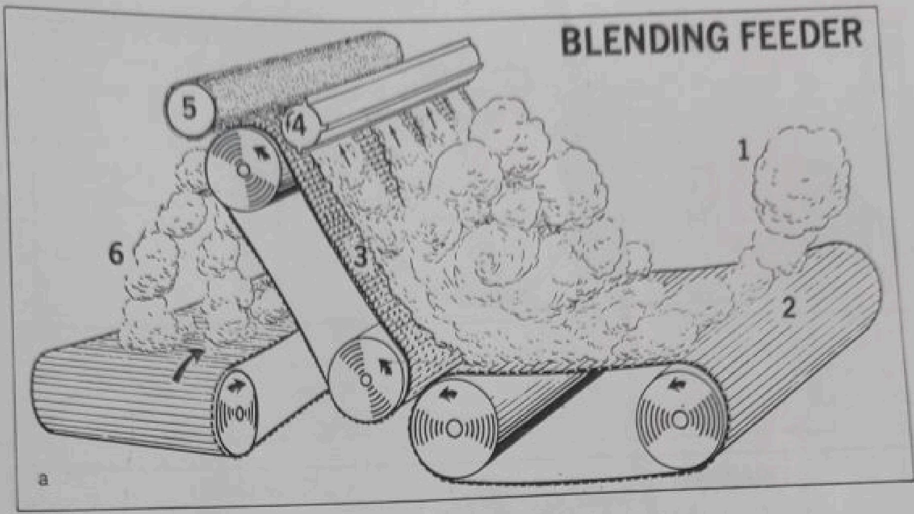
Because the production of cotton yarn lends itself to a simple description of the manufacturing operations that make staple fiber into yarn, cotton fiber has been used in this chapter to illustrate the spinning process (see Figure 2-1). It must be remembered, however, that all other fibers pass through spinning operations, although, of course, there are differences that will be explained in the chapters dealing with the various fibers. One such difference occurs when long strands, or filaments, such as silk, are used rather than staple. In such instances, the required number of filaments is simply twisted together in a ropelike fashion as described in the paragraphs on the manufacture of silk yarns in Chapter 16.

The development of short fibers, or staple, into yarn, when stated in terms of basic manufacturing processes, is as follows: carding, combing, drafting, twisting, and winding. As the fibers pass through these processes, they are successively formed into *lap*, *sliver*, *roving*, and finally *yarn*. Here are the manufacturing operations in which these stages occur:

1. Lap to card sliver by the carding process
2. Card sliver to comb sliver by the combing process (if the fiber is to be combed)
3. Sliver to roving by the drafting, or drawing-out, process
4. Roving to yarn by further drafting and twisting process
5. Yarn reeled on bobbins, spools, or cones by the winding process

Blending, Opening, and Cleaning. The cotton arrives at the mill in large bales weighing about 500 pounds [225 kilograms (kg)] each. The compressed mass of raw fiber must be removed from the bales, blended, opened, and cleaned. Blending

Figure 2-1 Schematic of conventional ring spinning: (*a*) Cotton is passed from bales (1) onto apron (2). Apron moves cotton to blending apron (3). Blending apron has sharp spikes that raise cotton until part of it is knocked off by roll (4). Some of the cotton stays on apron. The cotton knocked back by roll (4) continues to churn and blend until picked up again by apron. Another roll (5) strips off cotton that was not knocked back by previous roll (4). Cotton falls on conveyor belt (6) and is carried to next process. (*b*) Lint cotton falls on apron (1) and passes between feeder rolls (2) to beater cylinder (3). The rapidly whirling beater blades take off small tufts of cotton, knock out trash, and loosen up the mass. The two screen rolls (4) are made of screen material, and air is sucked out of them by fan (5). This draws the cotton from beater and condenses it on the surface of the screen rolls from which it is taken and passed on by the small rolls (6). Air suction through cotton takes out dirt and trash. Conveyor belt (7) passes cotton to another type of beater (8). (Beaters shown are typical of the many types used.) From beater, the cotton passes to a conveyor and is carried to picker. (*c*) Cotton in a loose mass enters picker, which is a series of beaters (2) and screen rolls (3) similar to those described under "opening" but progressively more refined. At the final output of beater and screen system (4), cotton has again been formed into a sheet, or lap. At this point, the "evener" operates to feed more or less cotton to make lap perfectly uniform as it is either wound up into a lap roll (5) on winding rolls (6) and then taken to the carding process, or conveyed as a lap by a chute feeder directly to the card.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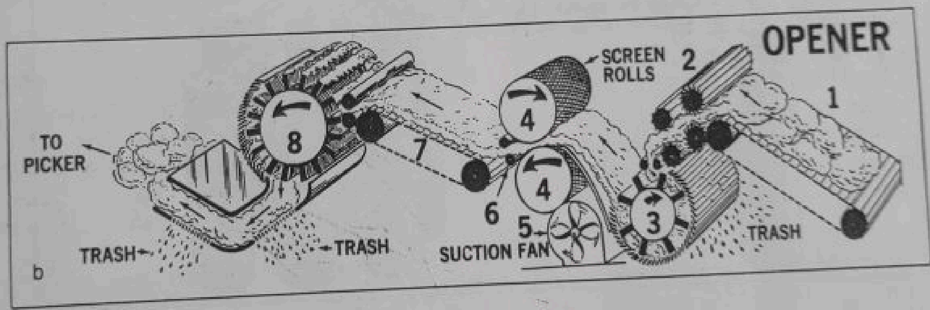
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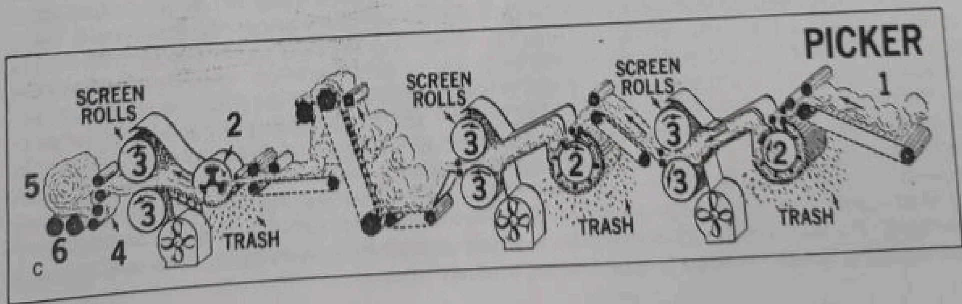
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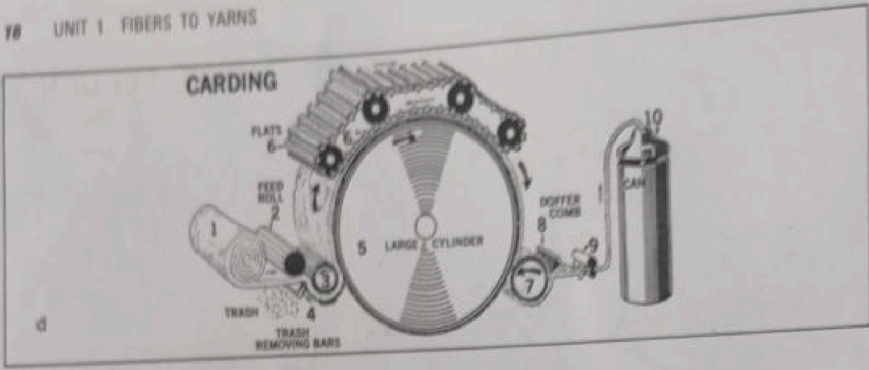

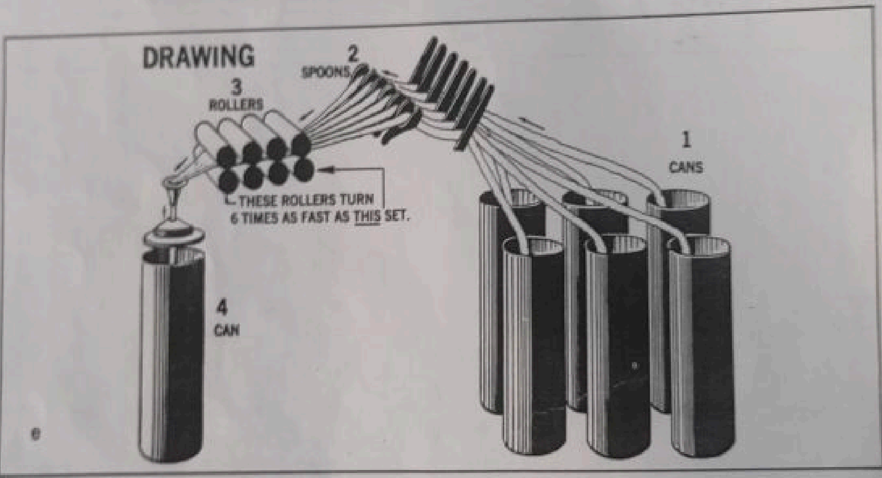

Figure 2-1 (*Continued*) (*d*) The lap (1) from picker unrolls, and feed roll (2) passes cotton to the licker-in roll (3) (covered with sawtoothlike wire). The licker-in roll passes fiber against cleaner bars (4) and gives it up to large cylinder (5), which passes between the thousands of fine wires on surface of cylinder and on flats (6). The cotton follows large cylinder to doffer cylinder (7), which removes lint from large cylinder. The doffer comb (8) vibrates against doffer cylinder and takes lint off in a filmy web that passes through condenser rolls (9), coiler head (10), and then into can. The sliver may be passed from can to combing for further removal of foreign matter and parallelization of fiber or directly to drawing. (*e*) Here, six cans (1) that were filled at cards feed each drawing from delivery. The spoons (2) are connected so that if any one of the six slivers from can should break, the machine automatically stops. This prevents making uneven yarn later. Each of four sets of rolls (3) runs successively faster than preceding set. The last set runs approximately six times as fast as the first set; consequently, sliver coming out is the same size as each one of six going in, but is attenuated to six times the length per minute. The sliver is neatly coiled again in roving can (4) by coiler head. The sliver is now much more uniform and fibers are much more nearly parallel. The sliver is now ready for roving frames. In actual practice, drawing is usually repeated.

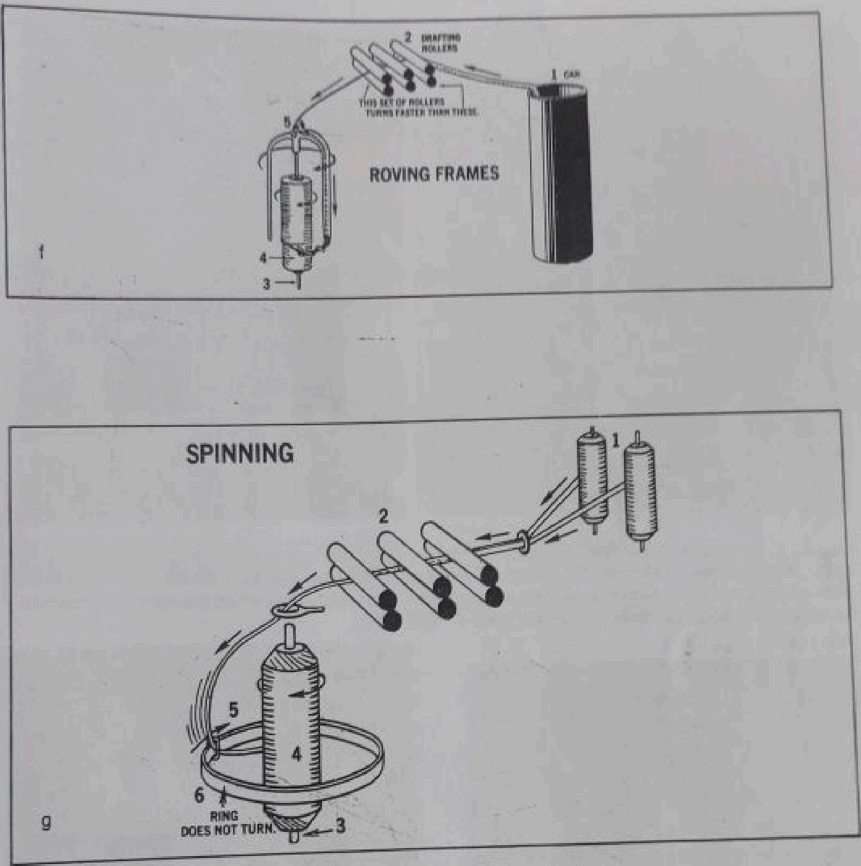

Figure 2-1 (*Continued*) (*f*) The can of sliver (1) from drawing frames is fed between three sets of drafting rolls (2). Each following set of rolls runs faster than preceding set. This pulls sliver and thins it down, making fibers nearly parallel. The spindle (3) turns flyer (5) and is driven at a constant speed. The front rolls (nearest flyer) are set at a speed that gives strand coming out of the rolls a predetermined number of turns of twist per inch as it moves along between rolls and flyer. The bobbin (4) is driven by a source separate from gear that drives spindle and flyer. The bobbin is regulated to turn automatically at a speed sufficiently faster than flyer, which causes roving to wind on bobbin at same rate it is delivered by front roll. (*g*) The principle for spinning is the same as that used for roving except that the operation is more refined and a ring and traveler are used instead of the flyer. From bobbin (1) roving is fed between sets of drafting rolls (2) to draw strand down to its final desired size. The spindle (3) turns bobbin (4) at a constant speed. The front set of rolls is adjusted to deliver yarn at a speed sufficient to insert desired amount of twist as strand moves along. The traveler (5) glides freely around ring (6). The tension caused by drag of traveler causes yarn to wind on bobbin at same rate of speed as it is delivered by rolls. *(All illustrations and copy courtesy of Bibb Manufacturing Co.)*

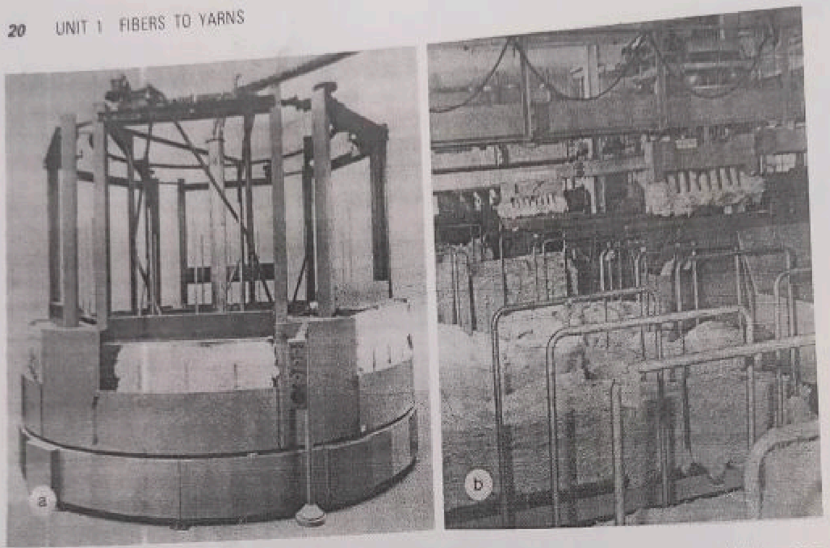

Figure 2-2 Two types of fiber blending machines: (a) Karousel opener plucks cotton from several bales on a rotating basis and passes fiber onto an automixer for blending. (Courtesy American Rieter Co., Inc.) (b) Bale-O-Matic grasps batts of fiber from opened bales and distributes them in a predetermined manner among hoppers for mixing and blending. (Courtesy Automatic Material Handling, Inc.)

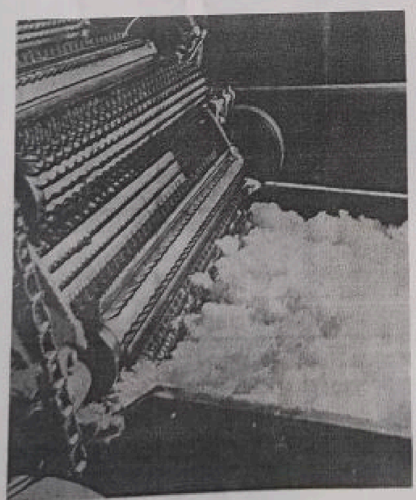

Figure 2-3 Cotton going through the opening machine where the fibers are loosened. (Courtesy West Point Pepperell Inc.)

is necessary so as to obtain uniformity of fiber quality; opening is necessary in order to loosen hard lumps of fiber and disentangle them; cleaning is required to remove trash—such as dirt, leaves, burrs, and any remaining seeds—in order to prepare the fiber for spinning into yarn. These functions are accomplished through a continuous series of stages.

Mechanical bale pickers pluck thin, even layers of the matted fiber from each of a predetermined number of bales in turn and deposit them into a hopper (see Figure 2-2). The fiber is mixed and passed to an *opener*. As the mass of fiber passes through the opener, cylinders with protruding fingers open up the lumps and free the trash (see Figure 2-3). The kind and number of cylinders, or beaters, employed depend upon the type of cotton that is being processed; the commonly used porcupine beater revolves about 1000 revolutions per minute. As the cotton is opened, trash falls through a series of grid bars. When the cotton emerges from the opener, it still contains small tufts with about two-thirds of the trash. It may be conveyed as a *lap*, which is a loosely entangled mass about 1 inch [2.5 centimeters (cm)] thick and about 40 inches [1 meter (m)] wide (see Figure 2-4), or it may be fed by chute directly to the card for further cleaning and fiber separation.

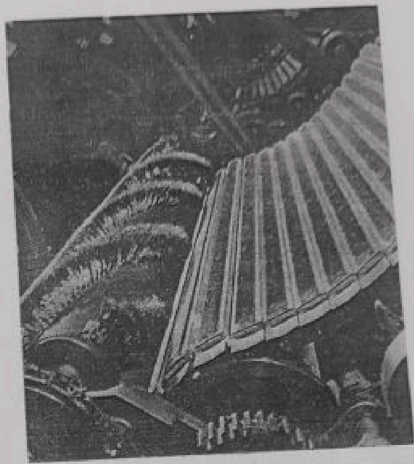

Figure 2-5 Inside the carding machine, where the brushes clean and straighten the fiber. *(Courtesy West Point Pepperell Inc.)*

Carding. Before the raw stock can be made into yarn, the remaining impurities must be removed, the fibers must be disentangled, and they must be straightened. The straightening process puts the fibers into a somewhat parallel lengthwise alignment. This is necessary for all staple fibers; otherwise, it would be impossible to produce fine yarns from what is originally a tangled mass. This initial process of arranging the fibers in a parallel fashion is known as *carding*. The work is done on a carding machine.

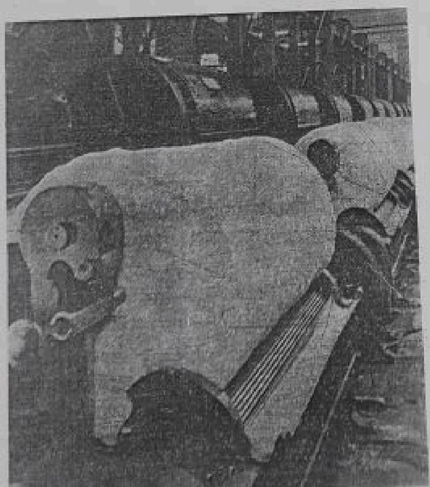

Figure 2-4 Cotton lap roll from the picker-beater where dust, leaf, twigs, and other foreign matter have been removed. *(Courtesy West Point Pepperell Inc.)*

The lap is passed through a beater section and drawn on a rapidly revolving cylinder covered with very fine hooks or wire brushes (see Figure 2-5). A moving belt of wire brushes slowly moves concentrically above this cylinder. As the cylinder rotates, the cotton is pulled by the cylinder through the small gap under the brushes; the teasing action removes the remaining trash, disentangles the fibers, and arranges them in a relatively parallel manner in the form of a thin web. This web is drawn through a funnel-shaped device that molds it into a round ropelike mass called *card sliver*, about the thickness of a broomstick (see Figure 2-6). Card sliver produces *carded yarns* or *carded cottons* serviceable for inexpensive cotton fabrics.

Figure 2-6 Sliver leaving the carding machine, where the cotton has been further cleaned and disentangled. (Courtesy West Point Pepperell Inc.)

Figure 2-7 Combed slivers are combined as they leave the combing machine to further increase density and compactness of future yarn. (Courtesy West Point Pepperell, Inc.)

Doubling. After carding, several slivers are combined. This results in a relatively narrow lap of compactly placed staple fibers. The compactness of these fibers permits this cotton stock to be attenuated, or drawn out, to a sliver of smaller diameter without falling apart.

Combing. When the fiber is intended for fine yarns, the sliver is put through an additional straightening called *combing*. In this operation, fine-toothed combs continue straightening the fibers until they are arranged with such a high degree of parallelism that the short fibers, called *noils*, are combed out and completely separated from the longer fibers. (This procedure is not done when processing man-made staple fibers because they are cut into predetermined uniform lengths. Since these fibers do not need the combing separation, they are processed for spinning into yarns by the Direct Spinner, the Perlok Process, or the Pacific Converter, depending upon the desired end uses of the yarns. These techniques are discussed more fully in the description of spun rayon staple yarn in Chapter 18.)

The combing process forms a *comb sliver* made of the longest fibers, which, in turn, produces a smoother and more even yarn (see Figure 2-7). This operation eliminates as much as 25 percent of the original card sliver; thus almost one-fourth of the raw cotton becomes waste. The combing process, therefore, is identified with consumers' goods of better quality. Since long-staple yarns produce stronger, smoother, and more serviceable fabrics, quality cotton goods carry labels indicating that they are made from *combed yarns* or *combed cottons*.

Drawing. The combining of several slivers for the drawing, or drafting, process eliminates irregularities that would cause too much variation if the slivers were put through singly. The draw frame has several pairs of rollers, each advanced set of

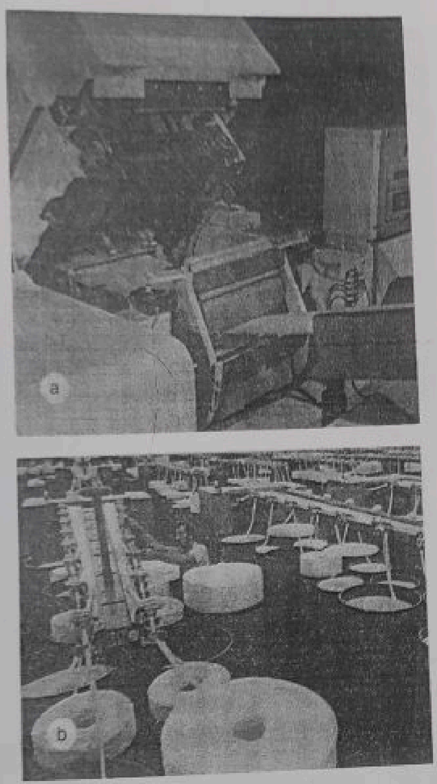

Figure 2-8 (a) Close-up of sliver emerging from drafter (drawframe). Needles, acting like a brush in the section preceding the rollers, straighten the fibers; the rollers draw out the sliver. (*Courtesy Warner & Swasey Textile Machine Co.*) (*b*) In drawing, multiple slivers are combined and drafted into a single strand for the next process—roving. (*Courtesy West Point Pepperell, Inc.*)

which revolves at a progressively faster speed. This action pulls the staple lengthwise over each other, thereby producing longer and thinner slivers. After several stages of drawing out, the condensed sliver is taken to the slubber, where rollers similar to those in the drawing frame draw out the cotton further. Here the slubbing is passed to the spindles, where it is given its first twist and is then wound on bobbins (see Figure 2-8).

Roving. These bobbins are placed on the roving frame, where further drawing out and twisting take place until the cotton stock is about the diameter of a pencil lead. There are two stages of roving: intermediate and fine. The operations are identical, but each machine yields a finer product than the stock it received. *Roving* is the final product of the several drawing-out operations. It is a preparatory stage for the final insertion of twist. To this point, only enough twist has been given the stock to hold the fibers together. Roving has no tensile strength; it will break apart easily with any slight pull.

Spinning. The roving, on bobbins, is placed in the spinning frame, where it passes through several sets of rollers running at successively higher rates of speed and is finally drawn out to *yarn* of the size desired (see Figure 2-9). Spinning ma-

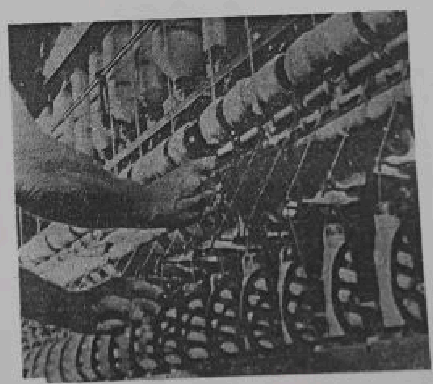

Figure 2-9 On the spinning frame, the roving passes from the top through a series of rollers that draw out the cotton into a thread. The thread is twisted as it winds onto the bobbin. (*Courtesy West Point Pepperell Inc.*)

chines are of two kinds: ring frame and mule frame. The ring frame is a faster process, but produces a relatively coarse yarn. For very fine yarns, such as worsted, the mule frame is required because of its slow, intermittent operation. The ring frame, which is in general use, is more suitable for the manufacture of cotton yarns for mass production. Its hundreds of spindles, whirling thousands of revolutions a minute, and its constant spinning action provide a fast operation. The ring spinning frame completes the manufacture of yarn (1) by drawing out the roving, (2) by inserting twist, and (3) by winding the yarn on bobbins—all in one operation. The bobbins of yarn are removed for such processing as may be desired; for example, the yarn may be reeled into skeins for bleaching or may be wound on *cheeses*, or spools, for ultimate weaving (see Figures 2-10 and 2-11).

Yarn Twist. The amount of twist is an important factor in finished consumers' goods. It determines the appearance as well as the durability and serviceability of a fabric. Fine yarns require more twist than coarse yarns. Warp yarns, which are used for the lengthwise threads in woven fabrics, are given more twist than

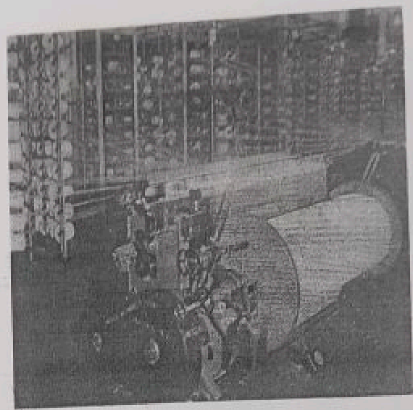

Figure 2-11 From spools or cones, mounted on creel, separate yarns are wound on a warp beam. *(Courtesy Bibb Manufacturing Co.)*

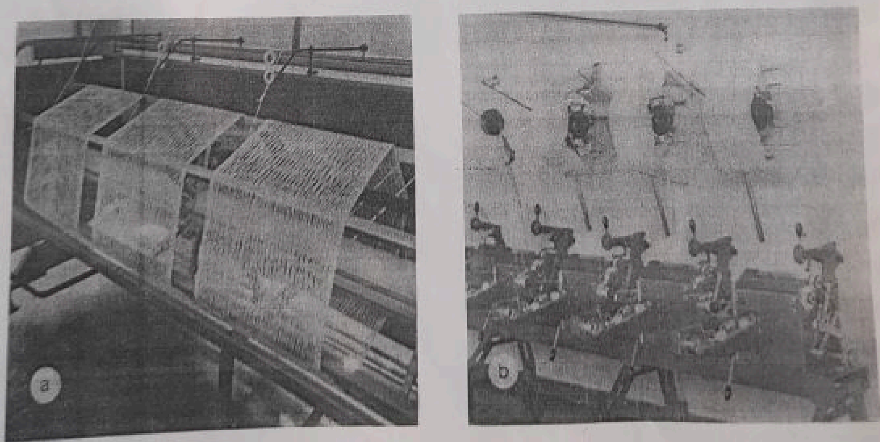

Figure 2-10 *(a)* Skeins of yarn have to be built up in the right yarn angle to be self-supporting. *(b)* The skeins are subsequently reeled onto spools for fabrication into material. *(Courtesy Stellamacor, Inc., New York. Machines manufactured by Zerbo, Italy.)*

are filling yarns, which are used for the crosswise threads. To retain the twist in the yarns and prevent any tendency to untwist or kink, the yarns are given a twist-setting finish with heat or moisture, depending upon the kind of fiber used.

The amount of twist also depends upon the type of fabric to be woven:

1. Yarns intended for soft-surfaced fabrics are given only a slack twist. They are called *soft-twisted yarns*.
2. Yarns intended for smooth-surfaced fabrics are given many twists. Such *hard-twisted yarns* contribute strength, smoothness, elasticity, and some wrinkle resistance to fabrics.
3. Yarns intended for crepe fabrics (with rough, pebbly, or crinkled surfaces) are given a maximum amount of twist, which also adds wrinkle resistance.

The direction of twist may be observed by holding the yarn in a vertical position. If the spirals conform to the direction of the slope of the central part of the letter S, the yarn has an S twist; if they conform to the slope of the letter Z, the yarn has a Z twist (see Figure 2-12).

Permanent crepe effects, such as chiffon, georgette, crepe de chine, canton, and flat and French crepes, are produced by the use of hard-twisted yarns, some of which have left twist, others right twist. These yarns are placed alternately in the warp or in the filling, or in both. (Another satisfactory method of obtaining crepe effects during the construction of the fabric is by the use of slack warp yarns, which may or may not be wound on a separate warp beam. These yarns are held less taut than the other warp yarns and produce a permanent crinkled pattern. Seersucker and matelassé are produced in this way and prove very serviceable.) When the finished fabric is later washed or

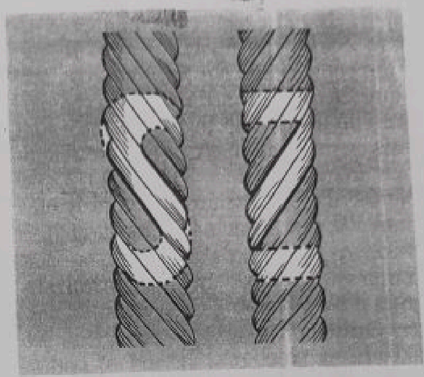

Figure 2-12 The S and Z twists are diagrammed here. The importance of the direction of the twist is illustrated in the diagrams of thrown silk threads shown in Chapter 16.

dyed, such yarns kink in different directions, producing the crepe surface.

Yarn Count. In the spinning process, there is always a fixed relation between the weight of the original quantity of fiber and the length of the yarn produced from that amount of raw material. This relation indicates the thickness of the yarn. It is determined by the extent of the drawing process and is designated by numbers, which are called the *yarn count*. This yarn count may be expressed according to the traditional method or by the newer *tex* system, which is based entirely upon the metric system of measurement.

The standard for the yarn count in cotton is 1 pound of fiber drawn out to make 840 yards of yarn; the resultant thickness or size is known as count number 1, or Ne 1. If the yarn is drawn out farther, so that 1 pound makes twice 840 yards, it is identified as Ne 2 or 2s. Thus, Ne 2 yarn will be finer than Ne 1. A still finer yarn is Ne 10, as it indicates that 1 pound of cotton is drawn out to ten times

Practical - 5

Yarn Identification

Objective

To identify the yarn.

Definition of yarn

A yarn is a strand of natural or manmade fibres or filaments that have been twisted together.

Definition of twist

It is the number of spiral turns given to a yarn in order to hold the constituent of the fibres together.

Material required : Fabric

To study a yarn, first unravel it from the fabric. Then holding the yarn between your thumb and first finger of both hands, slowly untwist it by turning one end of the yarn in the opposite direction from the yarn twist.

Yarn Classification

Yarn have been classified in three types;

1. Simple yarns
2. Complex or novelty yarns
3. Textured yarns

1. Simple yarns

Simple yarns are those with uniform size and regular surface having a varying degree of twist ranging from loose to moderate, light to hard twist. They are generally made from one type of fibre. They are further divided into;

a) Single yarn

b) Ply yarn

c) Cord yarn

d) Crepe yarn

a) Single yarn

It is the basic assemblage of the fibres twisted together. It is formed by twisting operation.

b) Ply yarn

It is formed by a second twisting operation of the spinning machine by combining two or more single yarns. Each part of the yarn is called ply. The twist are brought about by twister. Most ply yarns are twisted in the opposite direction to the twist of single yarn from which they are made. Ply increases the diameter, strength and quality of yarn. In naming the ply yarn the number of singles used is written before the word ply e.g. If two singles are used then yarn is called two ply.

c) Cord yarn

Two or more plied yarns may be twisted together to form the cord yarn. Some types of sewing threads and ropes belongs to this group. In naming a cord, it is necessary to indicate the number of plies and singles used in the cord e.g. 4-5 ply indicates that each ply has five singles and four of these five ply yarns are combined in making the cord.

d) Crepe yarn

They are variations of simple yarn. They have high degree of twist and this tends to kink. The kinkiness gives fabric a rough texture but they are evenly twisted and even in size and therefore they are simple yarns.

2. Complex or Novelty yarns

Novelty yarns are made primarily for there appearance. Novelty yarns are made on twister with special attachments for giving different tensions to the different parts which gives the yarns loose, curled, twisted or loop yarns. Novelty yarns are defined as yarns that are irregular at regular intervals.

Novelty yarns has three basic parts.

1. Ground or base or core yarn

The core yarn controls the length & stability of the end product.

2. Fancy yarn/effect yarn;

Gives the aesthetic value to the finished product.

3. Binder yarn

Binder yarn is used to attach the effect yarn so that it remains in position.

Novelty yarns are further divided into;

a) Slub yarn

b) Flake yarn

c) Loop yarn or Boucle yarn or curl yarn

d) Spiral yarn or corkscrew yarn/eccentric yarn

e) Ratine yarn

f) Knot spot or nub yarn

g) Chenille yarn

h) Grandelle yarn

a) **Slub yarn**

Slub yarns, have soft untwisted areas at frequent intervals throughout their length. They are coarse, with slight twist, having varying diameter that show irregularities. The distance may be regular or irregular.

b) **Flake yarn**

Small tufts of fibres are inserted at regular or irregular intervals at the time of twisting and these tuffs are held in place by twist. The tufts may be of different colours.

By this method a yarn with uneven diameter can be produced. This type of yarn is limited to fancy effect uses.

c) **Boucle yarn or loop yarn or curl yarn**

In this yarn a coarse and thick base yarn is taken and effect yarn is fine.

It has projecting loops outside the body of the yarn at fairly regular intervals. These yarns are popular for knitted fabrics.

d) **Spiral yarn or corkscrew yarn/eccentric yarn**

In this yarns a coarse yarn is wound around a fine yarn, giving the effect of a spiral.

The thicker yarn is given a slack twist and wound spirally around the fine yarn, which is given a hard twist. They are used to give decorative spiral effect.

e) **Ratine yarn**

Ratine yarns are variations of spiral yarn. The effect yarn and core yarn are twisted in a spiral manner, but at intervals a longer loop is thrown out by effect yarn which is held in place by binder yarn.

Ratine yarns are very popular and the technique may be applied to all major fabrics.

f) Knot, spot or nub yarn

Nub yarns are made by twisting the effect ply around the core ply many times within a very short space, causing bumps or nubs that may be spaced at intervals along the yarn.

Two effect plies of different colours may be used and the knots arranged so that colours are alternated along the length of yarn.

g) Chenille yarn

It has a soft, fuzzy surface. The effect is achieved by a core of two yarns plied together and firmly holding short fufts of soft-twisted yarns between the twists along the core's length. The result is a yarn with a velvet like or pile surface.

h) Grandelle yarn

Ply yarns in which two single different colour threads are twisted together. These yarns are used to add colour effect.

3. Textured yarn

Texturing is a general term used for any continuous filament yarn whose smooth straight fibres has been displayed by the introduction of some form of crimp, curl or loop. This is used mainly for nyl[illegible]ns.

These yarns gives the fabric more permeability and fabric is more absorbing, elastic & comfortable & it reduces the development of static electricity.

Textured yarns are commonly classified as;

a) Stretched yarn

High extensibility & good elastic recovery. Bulk is moderate and it is used in stretch fabric e.g. for making hosiery articles, socks etc.

b) Modified stretched yarns

Stretch yarns are subjected to heat treatment and are more stable than stretch yarn e.g. for knitted fabric.

c) Bulk yarn

They have moderate stretch and used in sweaters, carpets, upholstery etc. Bulk like texture can be used with any kind of filament fibre or spun yarn.

Bulk texturing is done by Gear crimping, stuffer box method & air jet process. Any type of filament fibre can be used such as nylon, polyester, acetate etc.