Spun Yarn Technology
This book is dedicated to my wife
BETTY
Spun Yarn Technology

Eric Oxtoby, MSc, PhD
Formerly Senior Lecturer in Yarn Manufacture at Leicester Polytechnic
This book brings together important, but scattered, sources of information relating to spun yarn manufacture so that they form a coherent whole; it is intended to provide a comprehensive review of principles for newcomers to the industry, and a comprehensive reference source for the practising Textile Technologist. References to original sources of information are given at the end of each chapter.

For readers requiring more information, a very detailed review of the literature is given in the author's PhD thesis, part of which formed the basis for this present work. The thesis, entitled 'Spun Yarn Technology', 1979, may be referred to at Bradford University.

No attempt has been made to describe fibre production, although some reference to it is inevitable; readers should refer to appropriate text books where necessary.

Scientific research has revealed the principles underlying the previously existing rule-of-thumb methods, but the work has been carried out in isolated sections of the industry, such as cotton in Lancashire, wool in Yorkshire, jute in Scotland, etc., as well as in other countries, where different units of measurement were in use.

In recent years the traditional sectional boundaries of the spinning industry have been blurred by the impact of man-made fibres; Research Associations, originally formed to serve separate sections of the industry, have maintained closer liaison or even merged.

The spinning industry has reached the stage where the common features are more easily recognized, and yet sectional differences still exist. The book has been written using metric units and the Tex system for yarn counts, with little reference to other units.

Throughout the book many clear diagrams have been provided to aid the explanations given; however, it must be emphasized that the diagrams are not drawn to scale.

Although continuous filament yarns have been mentioned in passing, the book deliberately has been limited to the subject of spun yarn technology and closely related items.

The author hopes that this book will prove helpful to current students, to many of his past students who are awaiting its publication, and to others.

Eric Oxtoby, MSc, PhD
Leicester
Thanks are due to the many firms, research associations, and individuals who in any way have helped me to compile this book.

In addition to the donors of photographs, who are acknowledged on the respective Plates, I proffer my sincere thanks to:

Mr V. Craig, A.E. Aspinall Ltd, Manchester
Messrs Thomas Burnley and Son Ltd, Gomersal
Messrs Croone and Lucke, Stuttgart, Germany
Mr R. Maynard, Robert S. Maynard Ltd, Wilmslow
Messrs S.A.C.M. Mulhouse, France

Messrs W. Schlafhorst & Co., Germany
Mr H. Shaw, Shawmoor (Textile Machinery) Ltd, Stalybridge
Mr J. Clayton, John Sheard Ltd, Bradford
Mr M.I. Howard, Thibeau (Engineers) Ltd, Bradford
Messrs W.J. Whitehead Ltd, Bradford
Messrs Mossley Woolcombing and Spinning Co. Ltd, Mossley
Mr R. Brook, Messrs. Herbert Brown Ltd, Huddersfield
CONTENTS

1 INTRODUCTION 1

2 OPENING AND CLEANING 9

3 BLENDING AND MIXING 19

4 CARDING 25

5 ROLLER DRAFTING, DOUBLING, AND FIBRE CONTROL 46

6 AUTOLEVELLING 62

7 COMBING 73

8 PACKAGE FORMATION AND DRAWING PRIOR TO SPINNING 84
worsted; semi-worsted; carded cotton; combed cotton; flax; jute; spun silk.

9 THE SPINNING PROCESS
Classification of spinning machines. General features of conventional spinning machines: creels; roving traverse; top roller covering and pressure; underclearers; spindle drives; change speed devices; speed limitations; variable speeds; spindle pitch; lifter traverse; productive efficiency; piecening; automatic doffing; economics. General features of the spinning process: yarn strength; twist variation and yarn appearance; yarn thickness, compressibility and twist; production; end-breakages; twist formulae; yarn length contraction; fine count limit; fly waste.

10 FIBRE MIGRATION AND DISPLACEMENT
Characterization of migration. Factors influencing displacement: fibre; yarn; process.

11 INTERMITTENT SPINNING MACHINES
Mule spinning. The woollen mule cycle of operations: delivery; drafting; twisting; backing-off; winding-on. Centrifugal spinning.

12 CONVENTIONAL FRAME SPINNING MACHINES
Flyer spinning. Ring spinning: spindle arrangement; winding-on revolutions; twist variation; calculated twist; yarn tension; balloon theory; balloon collapse; control rings; moving lappets; rings and travellers; factors influencing spinning conditions; ring diameter; balloon height; spindle speed; traveller mass; spindle attachments; condenser yarn spinning; automatic underwinding. Cap spinning.

13 OPEN-END SPINNING
Principles. Advantages. Basic methods: vortex; axial; discontinuous; friction; rotor. Rotor spinning: fibre assembly; twist insertion and yarn withdrawal. Rotor machine features: opening methods; fibre transfer; bridging fibres; wrapper fibres; rotor design; bearings and drives. Technical aspects: twist and draft calculations; theoretical and calculated twist; cross-sectional number of fibres; change of draft and twist; yarn structure; cleanliness of fibre feed; sliver preparation; spinning tension and fine count limit; power consumption; rotor speed; rotor diameter; spinning twist and end-breakages; general features of rotor machines; economic aspects. Open-end yarn uses.

14 REPCO SELF-TWIST SPINNING

15 SPINNING DEVELOPMENTS

16 YARN FOLDING

17 YARN PREPARATION

18 STATIC ELECTRIFICATION AND ATMOSPHERIC CONTROL 198
Static: formation; dissipation; gaseous discharge; fibre conduction; anti-static conduction. Dissipation for the consumer. Atmospheric control: side effects; recommended processing conditions. Travelling cleaners.

19 YARN PROPERTIES 202

20 YARN FAULTS 217

21 SPECIALITY YARNS 220
Fancy yarns: condenser-spun; drawn-and-spun; spiral; diamond; multifold; gimp; mock Chenille; cloud; knop; loop; snarl; spiral; stripe; slub; eccentric; folded Chenille. Core yarns. Coloured yarns: solid shades; mixture shades; gill mixing; re-combing; mixing in drawing. Vigoureux (melange) printing. Imitation Vigoureux. Speciality coloured yarns: twist shades; single marl; marl; half marl; double marl; single mottle.

22 TOW-TO-SLIVER CONVERSION AND BULKED ACRYLIC YARN PRODUCTION 232
Comparison of methods. Cutting converters: crush cutting; double-cuts; fused fibres; fish food. Stretch-breaking converters: heater temperature; stretch ratio. Bulked acrylic yarns: general principles; blend proportions; pre-relaxation; yarn shrinkage; acrylic yarn counts.

APPENDIX: PROCESSING SEQUENCES 238

INDEX 245
INTRODUCTION

Linguistically the word yarn has connections with the Dutch ‘garen’ and the German ‘garn’ which both have their origins in the Old Norse (Old Icelandic) garn, meaning gut; this is related outside Teutonic to the Lithuanian ‘žárnė’ meaning intestine. Presumably long thin strips of this material were used to sew together pieces of skin to form garments, footwear, and shelter.

Yarn.

A yarn may be defined as a product of substantial length and relatively small cross-section of fibres and/or filament(s) with or without twist, used for interlacing in processes such as knitting, weaving, or sewing. This definition includes single, folded, and cabled yarns whether they are staple, continuous filament, monofilament, or zero twist, and whether they are made from such materials as paper, metal, film, or glass, for example.

Yarns are the product of a process called spinning; there are two distinctly different meanings of the word: firstly extrusion spinning, and secondly staple fibre spinning.

Continuous Filament Production

Extrusion

In the spinning of both silk and man-made continuous filaments, a fibre-forming substance is forced through the holes of a spinneret beyond which it solidifies in the form of filaments. An alternative arrangement is to force the polymer through a narrow slit to form a film which can then be divided into narrow strips. The production of textiles from film has been confined largely to the production of twine, cordage, carpet-backing, and sacks.

Because man-made fibres are widely used in the production of spun yarns, and continuous filament yarns may be used in conjunction with them, a brief outline of their production and principal properties is given here.

Filament drawing

After extrusion, continuous filaments may be subjected to a drawing process which stretches them. The term ‘stretch spinning’ applies specifically to a process involving substantial stretch for the production of high-tenacity filaments. Drawing improves the orientation of the molecules in the direction of the filament axis, improving filament strength, but reducing its extension at break. The method used may be either cold or hot drawing. The applications of the word ‘drawing’ should not be confused with the drawing operations which involve the drafting and doubling of staple fibres prior to spinning.

The product of filament extrusion may be in the form of either yarn or tow.

(1) Continuous Filament Yarn

In this case the spinneret must have the exact number of holes to produce a yarn with the mass per unit length and number of filaments required. Each spinneret must be followed by all the necessary apparatus to process the individual yarn produced, including some method of winding on to a package, and, when required, twist insertion. The small spinneret limits the output per head, and furthermore the yarn take-up system imposes speed limitations.
and consumes a considerable amount of power. Continuous filament yarns are composed of one or more filaments which run the whole length of the yarn, a filament being defined as a fibre of indefinite length. Monofilament yarns contain only one filament, whereas multifilament yarns contain a number of filaments alongside each other; continuous filament yarns may be of the following types:

(i) **Smooth filament yarns**

In these, the filaments are smooth and straight, lying close to each other, forming a compact thread. They are sometimes referred to as ‘flat’ filament yarns (which is misleading), or ‘producer’ filament yarns — a term best avoided in these days of producer-textured yarns.

(ii) **Textured filament yarns**

These yarns may be divided into two main groups:
(a) Bulked filament yarns which have been treated physically or chemically to have a notably greater apparent volume or bulk, sufficiently stable to withstand yarn processing tensions and the normal forces exerted on garments during wear. There are various methods of obtaining the bulk effect.
(b) Stretch filament yarns, made from thermoplastic continuous filaments, which are capable of a pronounced degree of stretch and rapid recovery. This property is conferred on yarn which has been subjected to a combination of deforming, heat setting, and developing treatments. Such yarns may have more bulk in the unstretched form than in the stretched form. Stretch yarns may be subdivided into two major groups: crimped (or non-torque) yarns, and twist (or torque) yarns.

(iii) **Speciality filament yarns**

A variety of speciality yarn may be made, including:
(a) Aerated yarn. The filaments of such a yarn enclose bubbles of a gas.
(b) Bicomponent yarn in which each filament is composed of more than one type of polymer; after wet processing, bulk or stretch properties may develop.
(c) Elastomeric yarns, composed largely of segmented polyurethane filaments which exhibit rapid recovery from extensions up to about 600%
(d) Metallic yarns, which provide a very shiny appearance often exploited for decorative effect. They may be extruded metal strip or continuous filament yarn on which metal is deposited; a clear or coloured protective outer covering is used.

(2) **Continuous Filament Tow**

This is a large number of filaments collected into a loose strand substantially without twist. It is converted into staple fibre by either cutting or breaking before being passed through yarn manufacturing processes to become a spun staple fibre yarn. For its production each spinneret may have thousands of holes, permitting high rates of production. Because the tow is fairly robust, a relatively simple form of delivery is sufficient either to deliver the tow direct into a polythene lined carton, or alternatively to cut it into staple fibre before packing it under pressure. These forms of delivery consume less power and place less restriction on the speed of delivery, with the result that a given mass of tow or staple fibre is usually much cheaper than an equal mass of the same material in continuous filament yarn form. Staple fibre has a limited maximum fibre length, such as with cotton or wool; the maximum fibre length depends on the particular quality of fibre under consideration.

**Spun Yarn Production**

Spun yarns are produced by placing a series of individual fibres together to form a continuous assembly of overlapping fibres, usually bound together by twist. ‘Staple fibre yarn manufacture’ is the collective term which describes the processes involved in this branch of yarn production, with staple fibre spinning being the last process in the production of a single spun yarn. All the natural fibres (including waste silk, but excluding continuous filament silk) occur in staple fibre form, and most man-made fibres also are available in that form.

**Drafting**

This is frequently employed in the processing of fibre assemblies prior to staple fibre spinning. It consists of passing a continuous assembly of fibres between relatively slowly rotating back rollers, and then between a pair of front rollers running at a higher surface speed (*Figure. 1.1*) In this way the fibres are caused to slide past each other so that the fibre assembly becomes longer and thinner; in addition, fibre parallelization may be improved. The back and front rollers can be seen in *Plate 10*. It is important to realize that the drafting process does not cause any significant elongation of the individual fibres — it merely re-arranges their relative positions as they pass through the drafting zone between the two sets of rollers. The draft imposed is usually expressed as a ratio:

\[ \text{Input mass per unit length} \div \text{Output mass per unit length} \]
Basic operations in the production of spun yarns

Input fibres in one strand
Relatively slow surface speed
Delivered fibres
Relatively fast surface speed
Front rollers
Back rollers

Figure 1.1 A simple drafting zone

Alternatively it may be calculated from:
front roller surface speed
Back roller surface speed
Output length per unit mass
Input length per unit mass

Doubling

Doubling is the feeding of two or more fibre assemblies simultaneously into a drafting zone so that they are combined together and delivered as one fibre assembly, the purpose being to promote regularity and fibre mixing. It should not be confused with the term ‘doubling’ which is used in Lancashire to mean the folding together of two or more single yarns to form a folded yarn. Doublings are represented in Figure 1.2, and can be seen at the back of the drawframe in Plate 17.

Spun Yarn Types

There are two main groups of spun yarn types:

(1) **Drawn-and-spun yarns**

These yarns are produced from fibres which have been subjected to a series of preparatory drafting and doubling operations immediately prior to the spinning process; collectively these operations are called a drawing set.

This group may be sub-divided into two sections:

(i) **Carded yarns and combed yarns**

These are made from relatively long fibres from which some short fibres may have been removed. Consequently these yarns are relatively smooth, compact, and strong. Carded yarns are produced from fibres which have been carded, whereas combed yarns are produced from fibres which have been combed subsequent to previous preparatory processes (which frequently include carding). Systems in this section are: long staple, which includes worsted and flax; and short staple, which includes carded cotton and combed cotton.

(ii) **Prepared yarns**

In this case there is no significant removal of short fibres. Yarns of this type include jute and semi-worsted. Wools processed on the long wool ‘preparing’ system are not included in this group because they are later combed and made into worsted yarns.

(2) **Condenser-spun yarns**

These yarns are spun direct from threads which have been consolidated by a rubbing action from strips of card web. This method is generally used for relatively short fibres although carpet yarns are often an exception to this rule; a low draft is applied at the spinning process only. The result is that yarns of this type have a disorientated fibre arrangement, conferring bulk, but a lower yarn strength. Yarns of this type include woollen, condenser cotton, and silk noil yarns.

Basic Operations in the Production of Spun Yarns

All staple fibres follow a similar basic routine of conversion to spun yarn although man-made fibres do not require the cleaning which is necessary for natural fibres. The general outline of the processes is as follows:

(1) **Preliminary processes**

(i) **Cleaning**

This is necessary with natural fibres in order to remove the impurities present in the raw fibre
before further processing can take place. The cleaning process may be chemical, physical, or a combination of the two, depending on the nature of the impurities.

(ii) Opening and disentangling
Opening may be necessary after the cleaning operation, or it may form part of the cleaning operation. In the case of man-made fibres although cleaning is not required, it is often necessary to open the fibres because they have been closely packed in a bale or other container.

(iii) Blending
This may be necessary to ensure uniformity of product by eliminating variations between different sources of fibres or in the case of man-made fibres between different production runs. Product properties and price are other factors which influence blending.

(2) Formation of a continuous strand
This is frequently performed by a carding process, although it may sometimes be performed by some other operation such as long wool preparing or tow to sliver processing in the case of man-made fibres. It enables subsequent processes to take place more conveniently, and is the initial formation of continuity in order to produce a yarn. Continuity is more easily achieved with a relatively thick fibre assembly which at this stage is twistless and is called a sliver. A sliver may be defined as a long continuous assembly of overlapping fibres held together by cohesion without the aid of twist.

(3) Reduction of strand thickness
(i) By division
This method is used in the production of condenser spun yarns; the carded web of fibres is divided into narrow strips before being spun into yarn.

(ii) By drawing
This involves the use of a series of operations, collectively called a drawing set, using drafting and doubling to reduce the sliver thickness.

(4) Twist insertion
A conventional spun yarn has twist inserted into it to prevent fibre slippage by increasing the inter-fibre friction.

(5) Ancillary processes
Processes such as folding, winding, warping, and reeling may be necessary to present the yarn in the form required for further processing.

The way in which these basic operations are combined for the production of different yarn types is shown in more detail in the Appendix.

Terminology of Spun Yarns
Until the early twentieth century, natural fibres were the only fibres available in commercial quantities. They had widely differing physical and chemical properties which during the industrial revolution had led to distinctly different methods of processing using specialist machinery, frequently restricted to geographically localized areas, and resulting in yarns with distinctly different characteristics. The more recent availability of staple man-made fibre means that yarns can be produced by the different manufacturing systems from chemically identical fibres of the required dimensions. This development has blurred the traditional boundaries which separated the different systems. Nevertheless there may be differences between yarn properties when chemically identical fibres of different dimensions are processed on different systems, and so it is prudent to use distinctive yarn descriptions which indicate these potential differences.

The hyphenated suffix ‘-spun’ denotes staple man-made fibre either 100% or blended. The respective prefix in the second column of Table 1.1 indicates the processing system used. For example, a worsted yarn is processed from 100% combed wool, whereas a worsted-spun yarn contains fibre other than wool which has been processed on machinery of the type originally designed for the production of worsted yarn; the man-made fibre may be uncombed.

Yarn Thickness
Yarn thickness is difficult to measure because of the ill-defined yarn surface and inherent compressibility.

It cannot be too greatly emphasised that there is no such thing as spun yarn thickness in the absolute sense; under a transverse load yarn cross-sectional shape deforms to an extent largely determined by the compressive force applied. Many methods have been devised to measure yarn thickness directly, and some methods take into account the differences in yarn thickness which occur when different loads are applied. Such methods, however, although useful
Table 1.1 Spun yarn descriptive terms

<table>
<thead>
<tr>
<th>Yarns spun from 100% natural fibre</th>
<th>Yarns containing other fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>worsted (100% combed wool)</td>
<td>worsted-spun</td>
</tr>
<tr>
<td>woollen&lt;sup&gt;(1)&lt;/sup&gt; (100% wool)</td>
<td>woollen-spun&lt;sup&gt;(1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>carded or combed cotton</td>
<td>cotton-spun</td>
</tr>
<tr>
<td>condenser cotton&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>condenser-spun&lt;sup&gt;(1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>jute</td>
<td>jute-spun</td>
</tr>
<tr>
<td>spun silk&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>silk-spun (or schappe-spun)</td>
</tr>
<tr>
<td>linen</td>
<td>flax-spun</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> 'condenser-spun' may also be used as a collective adjective for any yarn spun direct from consolidated strips of card web. Hence woollen, condenser cotton, and woollen-spun yarns may all be described as condenser-spun.  
<sup>(2)</sup> 'spun silk' means yarn produced from 100% waste silk as distinct from nett silk continuous filament yarns. The terms 'spun silk' and 'silk-spun' should not be confused.

for research purposes, are too time-consuming for everyday use in industry.

**Yarn Count**

Instead the accurate determination of the mass of a known length of yarn is universally used in commerce and industry. The data thus obtained may then be expressed in either of two ways:

1. Mass per unit of length. This is known as the direct method where a higher count number denotes a thicker yarn.
2. Length per unit of mass. In this, the indirect method, a higher count number denotes a thinner yarn.

It is important to realize that yarn diameter is related to \( V(yarn\ count) \), either directly in the case of the direct count systems, or inversely for the indirect count systems. This relationship holds for a range of different yarn counts which have been spun by the same method from the same fibre stock, but as yarn diameter is also influenced by factors such as fibre density, fibre configuration, and yarn twist, it does not follow that all yarns of the same count necessarily have the same diameter. For example, the following thickness and compression indices refer to a series of yarns spun on the worsted system; in each case the finished yarn was 37 tex:

<table>
<thead>
<tr>
<th>Thickness index (( \mu m ))</th>
<th>Compression index</th>
<th>Yarn composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>224</td>
<td>0.220</td>
<td>low-crimp nylon</td>
</tr>
<tr>
<td>266</td>
<td>0.193</td>
<td>merino wool</td>
</tr>
<tr>
<td>370</td>
<td>0.267</td>
<td>high-crimp nylon</td>
</tr>
<tr>
<td>530</td>
<td>0.265</td>
<td>bulked Orion</td>
</tr>
</tbody>
</table>

Compression Index indicates that the yarn undergoes a greater reduction in thickness for a given increase of measuring load than would a yarn with a lower Compression Index.

At least 29 different yarn counting systems, both direct and indirect have been developed either in different localities of the UK or in other countries. Industrial expansion and improved communications have rendered these older systems obsolescent. It is clearly illogical for knitters or carpet manufacturers, for example, both of whom use a multiplicity of yarn types, to purchase yarns which may be described by different yarn counting systems; there are at least fourteen systems for woollen yarns alone!

The idea of replacing all these systems with one Universal system was discussed for some considerable time; eventually it led to the Tex System being recommended.

**The Tex System**

At the Southport conference of the Textile Section of the International Organization for Standardization (ISO/TC 38) in 1956, a unanimous vote of delegations from twenty countries supported the resolution that tex should be recommended as the universal system for describing yarn mass per unit length. In 1957 a resolution was passed recommending that all International and National Textile Federations and Associations should do everything possible to bring the Tex System into general use. Subsequent moves towards the adoption of the Tex System have met with resistance in many sections of industry, both in the UK and elsewhere. It is likely that this situation will continue in the UK until complete metrication takes place, when conversions to Imperial Units may be inconvenient.

The Tex System provides a simple means of numbering all filament and fibre assemblies according to a common basis of measurement. For very fine yarns or fibres, and for thick fibre assemblies,
Table 1.2 Tex system preferred units

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol for the unit</th>
<th>Symbol for the quantity</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>millitex</td>
<td>mtex</td>
<td>Tt</td>
<td>1 mtex = 1 mg/1000 m</td>
</tr>
<tr>
<td>decitex</td>
<td>dtex</td>
<td>Tt</td>
<td>1 dtex = 1 dg/1000 m</td>
</tr>
<tr>
<td>tex</td>
<td>tex</td>
<td>Tt</td>
<td>1 tex = 1 g/1000 m</td>
</tr>
<tr>
<td>kilotex</td>
<td>ktex</td>
<td>Tt</td>
<td>1 ktx = 1 kg/1000 m</td>
</tr>
</tbody>
</table>

*The symbol Ti is equivalent to the expression 'mass per unit length expressed in the Tex System; it is intended for use in formulae etcetera where a numerical value is not given.

Details of various yarn counting systems other than Tex are summarized in Table 1.3 along with the constants required for converting to and from the Tex System. The Tex System is used throughout this book, using the recommended fold-to-single notation for folded and cabled yarns.

The world 'count' or the symbol Tt is used to indicate the quantity 'mass per unit length expressed in the Tex System' for fibres, yarns, and other fibre assemblies; the word tex is only used to indicate the name of the unit.

Yarn twist direction is indicated by the letters S or Z according to the angle of fibre inclination (Figure 1.3). The amount of twist may be determined by standard tests. In this book the quantity of twist is expressed in turns per metre.

![Figure 1.3 Yarn twist: (a) S twist (b) Z twist](Image)

General Machine Features

Many machines in yarn manufacturing processes must be set to deliver a pre-determined count of sliver or yarn. Usually this is achieved by using a suitable number of teeth on the gear wheel reserved for this purpose. As the other components in the drive remain unchanged, it is convenient to calculate a gaugepoint (or machine constant). A gaugepoint is a number which represents the constant value relating the change wheel to the item which that change wheel controls, such as draft, or twist. The application of the gaugepoint depends on the position of the change wheel in the machine drive. In the case of draft, for example, the relationship may be gaugepoint/draft = change wheel, or draft/gaugepoint = change wheel, either of these methods may be used on different machines. Instead of change wheel, alternative arrangements may be used such as positively infinitely variable (PIV) drives, hydraulic variators, and variable speed motor drives.

Machine Sequences

During the production of a spun yarn, fibres usually have to pass through a number of sequential operations. This introduces problems of maintaining a balance of production from each stage in processing. Modern factories are designed to have a high productive efficiency; this usually entails a reduction in the range of end-products which may be produced. Flexibility may be eased somewhat at the increased cost of having a suitable 'reservoir' of material in work between each process.

General Comparison of Continuous Filament and Spun Yarns

Continuous filament yarns have the general advantages of fineness, strength, smoothness, uniformity, and resistance to pilling; as a result it is usual to find them used in light-weight fabrics which exploit these advantages.

Spun yarns have a characteristic texture which is often considered desirable. They can contain natural or man-made fibres, and one of the great advantages of spun yarns is their ability to exploit blends of fibres to satisfy requirements such as properties, processing, price, and end-use. Extensive use of colour mixing is possible with staple fibres, and frequently spun yarns can be produced cheaper from staple man-made fibre than can the same count of continuous filament yarn. For a given staple fibre there is a limit to the fineness of yarn which can be spun — known as the fine count limit —
consequently spun yarns are usually of thicker counts than continuous filament yarns. Exceptions to this general division include some heavy industrial fabrics where high strength is essential, and in situations where increased process efficiency can compensate for the higher cost of filament yarn; a good example of this is in the tufted carpet process where the use of a more expensive textured continuous filament pile yarn may increase the tufting process efficiency to such an extent that the end-product is cheaper than if a relatively cheap spun yarn were used instead.

**Table 1.3**

<table>
<thead>
<tr>
<th>Yarn count system</th>
<th>Symbol</th>
<th>Unit of yarn count</th>
<th>Conversion numerator&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos (American)</td>
<td>NA</td>
<td>100 yd/lb</td>
<td>4961</td>
</tr>
<tr>
<td>Asbestos (English)</td>
<td>NC</td>
<td>50 yd/lb</td>
<td>9921</td>
</tr>
<tr>
<td>Cotton bump</td>
<td>NB</td>
<td>1 yd/oz</td>
<td>31,000</td>
</tr>
<tr>
<td>Cotton (English)</td>
<td>NC</td>
<td>840 yd/lb</td>
<td>590.5</td>
</tr>
<tr>
<td>Cotton (Catalonian)</td>
<td>NC&lt;sub&gt;î&lt;/sub&gt;</td>
<td>500 canas/1.1 lb cat</td>
<td>565.9</td>
</tr>
<tr>
<td>Glass (USA &amp; UK)</td>
<td>Ni</td>
<td>100 yd/lb</td>
<td>4961</td>
</tr>
<tr>
<td>Linen (wet or dry spun)</td>
<td>NC&lt;sub&gt;î&lt;/sub&gt;</td>
<td>300 yd/lb</td>
<td>1654</td>
</tr>
<tr>
<td>Metric</td>
<td>Nm</td>
<td>1 km/kg</td>
<td>1000</td>
</tr>
<tr>
<td>Numero en puntos</td>
<td>Np</td>
<td>1320 m/lb dc Alcoy</td>
<td>358.7</td>
</tr>
<tr>
<td>Spun silk</td>
<td>NC&lt;sub&gt;î&lt;/sub&gt;</td>
<td>840 yd/lb</td>
<td>590.5</td>
</tr>
<tr>
<td>Typp (American)</td>
<td>Nt</td>
<td>1000 yd/lb</td>
<td>496.1</td>
</tr>
<tr>
<td>Worsted</td>
<td>NC&lt;sub&gt;î&lt;/sub&gt;</td>
<td>560 yd/lb</td>
<td>885.8</td>
</tr>
<tr>
<td>Woollen systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alloa</td>
<td>Na</td>
<td>11 520 yd/24 lb</td>
<td>1033</td>
</tr>
<tr>
<td>American cut</td>
<td>Na&lt;sub&gt;c&lt;/sub&gt;</td>
<td>300 yd/lb</td>
<td>1654</td>
</tr>
<tr>
<td>American run</td>
<td>Nar</td>
<td>100 yd/oz</td>
<td>310</td>
</tr>
<tr>
<td>Cardado Covilha</td>
<td>Np&lt;sub&gt;w&lt;/sub&gt;</td>
<td>1 m&lt;sup&gt;2&lt;/sup&gt;/g</td>
<td>5000</td>
</tr>
<tr>
<td>Dewsbury &amp; Batley</td>
<td>Nd&lt;sub&gt;î&lt;/sub&gt;</td>
<td>1 yd/oz</td>
<td>31 000</td>
</tr>
<tr>
<td>Galashiels</td>
<td>Ng</td>
<td>300 yd/24 oz</td>
<td>2480</td>
</tr>
<tr>
<td>Hawick</td>
<td>Nh</td>
<td>300 yd/26 oz</td>
<td>2687</td>
</tr>
<tr>
<td>Irish</td>
<td>Ni&lt;sub&gt;v&lt;/sub&gt;</td>
<td>1 yd/0.25 oz</td>
<td>7751</td>
</tr>
<tr>
<td>West of England</td>
<td>Nwe</td>
<td>320 yd/lb</td>
<td>1550</td>
</tr>
<tr>
<td>Yorkshire</td>
<td>Ny</td>
<td>256 yd/lb</td>
<td>1938</td>
</tr>
</tbody>
</table>

**DIRECT YARN COUNT SYSTEMS**

<table>
<thead>
<tr>
<th>Multiplying factors</th>
<th>Tex to yarn number</th>
<th>yarn no. to Tex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denier</td>
<td>Td</td>
<td>1 g/9000 m</td>
</tr>
<tr>
<td>Hemp, jute &amp; linen (dry)</td>
<td>Tj</td>
<td>1 lb/14 400 yd</td>
</tr>
<tr>
<td>Numero en quartos de onzas</td>
<td>To</td>
<td>0.24 onza/500 canas</td>
</tr>
<tr>
<td>Woollen (Aberdeen)</td>
<td>Ta</td>
<td>1 lb/14 400 yd</td>
</tr>
<tr>
<td>Woollen (American grain)</td>
<td>Tg&lt;sub&gt;a&lt;/sub&gt;</td>
<td>1 grain/20 yd</td>
</tr>
<tr>
<td>Woollen (Catalonian)</td>
<td>Tg&lt;sub&gt;c&lt;/sub&gt;</td>
<td>1 g/504 m</td>
</tr>
</tbody>
</table>

<sup>a</sup>Conversion numerator = count (tex units)

Indirect yarn count

Conversion numerator = Indirect yarn count
Introduction

composition and molecular structure, fibre length, cross-sectional shape and area; these largely determine the behaviour of fibres during processing into a yarn.

Secondary characteristics may be defined as the degree of variation of the primary ones. Differences in fibre dimensions and fabric structure may completely alter the comfort of apparel made from a given substance.

Derived characteristics include all the properties which inevitably follow from the primary and secondary characteristics. These include factors such as strength, moisture properties, dye uptake, abrasion resistance, and many others.

Additional characteristics are those which may be superimposed on to the basic fibre; examples are fibre surface properties and crimp.

However, it is possible for a given fibre characteristic to be either derived or additional, depending on the particular circumstances. For example, crimp may be derived in a bicomponent fibre, or additional by using a heat-set process in the case of a suitably homogeneous polymer.

Fibre properties with a direct bearing on processing performance include: fibre fineness and its variation; fibre length and its variation; the ratio of fibre length to fibre fineness; fibre tensile properties such as strength, extensibility, elongation at break, elasticity, and shear strength; bending and torsional rigidity; fibre friction, lubrication, and static electrification; fibre/moisture relations; fibre crimp; fibre cross-sectional shape; and fibre bulk and compressibility.

Fibre inflammability and resistance to microbiological degradation may also be considered.

Other fibre properties are more concerned with end-product characteristics such as lustre, fabric crease recovery, crease retention, fabric handle, and resistance to abrasion and pilling, and these must be borne in mind by the spinner.

The amount of moisture present in an assembly of fibres is usually expressed in terms of 'regain'.

Regain may be defined as the mass of water in the material expressed as a percentage of the oven-dry mass of the same quantity of material:

\[
\text{Percentage Regain} = \frac{100(\text{mass of water})}{\text{oven dry mass}}
\]

For each type of fibre a certain quantity of moisture added to the oven-dry mass is permitted for commercial purposes: this is known as the official regain.

An important characteristic which is unique to animal fibres is the 'directional frictional effect' (DFE). A fibre withdrawn from other fibres in the direction of root-end first develops less frictional resistance than when it is withdrawn tip-end first. DFE is of considerable importance in fabric finishing, but clearly it must also influence fibre movement in yarn manufacture, although its effect would be difficult to quantify.

Further Reading

FARNFIELD, C.A. and ALVEY, P.V. (Eds), Textile Terms & Definitions (7 Ed), Textile Institute (1975)

BOOTH, J.E., Principles of Textile Testing (3 Ed), Butterworths (1976)

SLATER, R., Textile Mechanics, Textile Institute (1977)


WRAY, G.R., Modern Yarn Production from Man-made Fibres, Buxton Press (1976)


HALL, A.J., Standard Handbook of Textiles (8 Ed), Butterworths (1976)


MONCRIEFF, R.W., Man Made Fibres (6 Ed), Butterworths (1975)


CHAPMAN, C.B. Fibres Butterworths 1974

OXTOBY, E. Yarn Thickness and Compressibility, J. Text. Inst., 58 293 (1967)
2

OPENING AND CLEANING

Automatic Feeders

Automatic feeders are widely used in opening and cleaning loose fibres in the early stages of yarn manufacture. The main object of a hopper feeder is to provide a constant supply of fibres spread uniformly across the width of the following machine. A widely used method is based on a weighing system which attempts to deliver fibre portions of equal mass at regular time intervals; an alternative arrangement is based on volume instead of mass. The most critical feed conditions are encountered in woollen carding; other processes such as cotton opening, wool scouring, and wool drying are not quite as exacting because there are more opportunities during subsequent stages of processing to correct any irregularities.

The basic arrangement of a traditional woollen carding hopper is shown in Figure 2.1. Fibres A are carried on B to maintain pressure against C1, the spikes of which pluck tufts of fibres from A. The reciprocating action of D returns surplus tufts to A before the rest of the fibres retained by C1 are removed by E1 to pass F to G which is mounted on horizontal balance-beam arms with adjustable counter-balance weights. When a sufficient fibre mass has been fed to G a balance-beam switch is actuated to disengage the drive to C1, and to close K. At fixed time intervals G is then opened by a time-actuated cam to permit the fibres to fall on to H; the balance-beam switch then restores the drive to C1 and opens K. The material on H is pushed forward by J to close gaps between successive weighs. A magnet may be fitted over C1 to collect any stray particles of ferrous metal.

The problem of uniform feeding depends on: a constant uniform supply of fibres to C1; the efficiency of the shutter mechanism of G; the sensitivity of the weighing mechanism which actuates the switch; and the uniformity of fibre distribution on H. The main factors which lead to variation of the weighs delivered by G include changes in the height of material at A, the inertia of G, and the irregular flow of fibres from E1; longer fibre length and increased fibre entanglement are associated with greater weigh variation. Weigh variations can be minimized by having as thin a feed into the weigh pan as is possible; clearly this may be contrary to production requirements.

An alternative is to have a 'trickle feed' whereby a fast flow of fibres is fed into G until the balance-point is almost reached, after which a reduced flow of fibres is permitted until the necessary fibre mass has been fed into G. In this arrangement E1 is usually replaced by a rotating clearer roller.

To reduce the variations caused by changes in the height of A, a self-emptying hopper may be used. The essential differences for this arrangement are shown in Figure 2.2. The horizontal lattice B is replaced by L which, aided by M, carries an even feed of fibres underneath L, to be collected by the
Opening and cleaning

Figure 2.2 Self-emptying hopper lattices

faster moving surface of C1. Direct contact of the mass of fibres with C1 is prevented by N; this method has never been widely used.

A double-hopper may be advantageous in high production carding for thick count production for end-products such as carpets. In this arrangement the first hopper is a large capacity version of that shown in Figure 2.1. Movement of C1 is controlled by the time-cam and the balance-beam switch to maintain a constant level of material in the second hopper. The second hopper is a self-emptying V-shape (Figure 2.3), the balance-beam switch controls C2 and actuates K. A double-hopper arrangement has been shown to reduce the percentage range of mass of 28 m (approximately) lengths of woollen slubbing from about 25% to 5%; a double-hopper is shown in Plate 5.

Further improvements to feed uniformity can be obtained by having the hopper weigh-pan wider than the machine being fed, and set diagonally above H at an angle of about 30° so that at any instant the input across the width of the machine being fed will include material from about five different hopper weighs; this method has not been widely used.

Blending systems may be designed which use a similar weighing principle; this has the advantage of the blend proportions not being influenced by component bulk differences.

A later development to the weigh-pan type of hopper has been the application of microprocessor control. This permits high-speed filling of the weigh-pan followed by a trickle feed, if required. Any difference between the required weight and the actual weight is taken into the microprocessor memory, which adjusts the cut-off point of subsequent weights to maintain a constant running average.

The volumetric continuous feed hopper has been introduced as an alternative to the weighing method of controlling fibre flow into worsted and semi-worsted cards where high production rates make the satisfactory performance of a weigh-pan mechanism difficult to attain. The essential difference is that the weigh-pan arrangement of Figure 2.1 is replaced by a vertical chute P as shown in Figure 2.4. The movement of B is controlled by a sensor which detects the amount of surplus material returned by D. The action of E2 packs fibres evenly into P up to the required level which is sensed by height detectors controlling the intermittent drive to C1. Adjustment of production is by setting the appropriate distance between: 1. the front and back walls of P, and 2. between C1 and D, and also by selecting the required speeds of Q and C1.

Figure 2.4 Volumetric continuous-feed hopper

The volumetric hopper is claimed to avoid the periodic gaps characteristic of the weighing hopper (hence J is not used), giving more uniform carding performance and hence permitting higher production rates. On the other hand, the hopper may need re-adjusting every time there is a change of fibre, and it is essential to have a uniform degree of fibre opening before carding throughout each batch of material processed.

For cotton processing the volumetric principle may be used in the form of a chute feed in which the
supply to the main hopper bin is from a reserve compartment containing a photoelectrically controlled constant height of fibres. A constant height of fibres is also maintained between the front and back panels of the delivery chute which are vibrated to compact the feed. The uniformity of feed into chute-fed cotton cards may not be as good as that from the traditional lap feed, but with the more widespread application of autolevelling this fact is of reduced importance.

Raw wool processing

Raw wool impurities

Raw wool contains a number of impurities which must be removed to facilitate yarn production.

The ‘natural’ impurities produced by the sheep itself include wool grease, suint (or dried sweat), and the excretion stains caused by dung and urine in the britch area; kemps may be regarded as an impurity in fine wools, but may be a desirable feature in coarse wools.

The ‘acquired’ impurities picked up by the sheep from its habitat include: minerals such as sand, dust, soil, and lime; vegetable matter such as burrs ie. prickly seed-appendages, seeds, and grass; and animal impurities which include insect parasites and pests.

The ‘applied’ impurities which are added to the coats of domestic sheep by the farmer include dips to rid the animal of parasites, and brands to indicate identification and ownership.

Removal of impurities from wool

Wool grease is normally removed by emulsion scouring although it can be removed by organic solvents. Suint is water-soluble and is removed in the wool scouring process. Wool grease and suint together may constitute approximately 10% to 50% of the mass of raw wool.

Excretion stained fibres are usually removed and treated separately from the bulk of the wool; such fibres frequently remain stained and weakened and may be used in some woollen blends.

Kemps are thick fibres which have been shed from the follicle and they usually resist dyeing. Kempy areas of the fleece are usually removed manually from fine wools and are treated separately from the bulk of the wool; they are common in carpet wools, for example, and are a desirable feature in coarse tweeds.

Except in some coarse wools and hairs, most of the mineral impurity is attached to the fibres by wool grease and so is released when the grease is removed during scouring.

Normally vegetable impurities tenaciously cling to the fibres and are removed mechanically during carding and, on the worsted system, during combing. Chemical removal of vegetable impurities by carbonizing is commonly used in woollen processing, and occasionally is used in worsted processing.

Vegetable and mineral impurities together may account for from approximately 5% to 25% of the mass of raw wool.

Animal pests are usually killed by chemical treatment during the normal husbandry exercised by the farmer — this is essential for the health of the animals and therefore for the standard of fibre produced; any living insects still present on the wool would perish during scouring.

Branding fluids now consist of lanolin-based emulsions which are emulsified during normal scouring, and the dips used by farmers to maintain the health of animals have their residues removed during scouring.

Wool opening and shaking

Hair fibres and low quality wools such as carpet wools frequently contain a considerable amount of dust and a relatively low percentage of grease. Mechanical beating in a shaking machine which contains revolving spiked rollers will release a lot of the dust prior to scouring. In order to avoid fibre entanglement and subsequent fibre breakage fine wools, particularly those intended for worsted processing, are not usually treated in this way although very dirty, burry, and entangled short merino wools may be an exception to this rule.

Wool scouring

The most widely used scouring method is the emulsion system in which either a combination of soap and alkali, or a synthetic detergent, emulsifies the wool grease.

Scouring should result in the wool being clean, lofty, and open (i.e. not entangled); with the change in appearance which takes place, the wool is increased in value considerably. If scouring is not properly conducted, perfectly good raw material may be ruined by discolouration, entanglement, and weakening. Good scouring is essential so that the fibres may be separated, to assist in processing, and to enable uniform dyeing to take place.

The agents used in conventional emulsion scouring, and their functions are:
**Water**

This dissolves the suint, provides a basis for the solutions used, provides a transport medium for the wool, and provides a medium through which heat may be applied. In the later stages it rinses the dirt, alkali, and soap (or synthetic detergent) from the wool.

**Alkali**

This is used because it is cheaper than soap and it improves the scouring efficiency of soap; the alkali normally used in woolscouring is sodium carbonate. Its functions are to act as a buffer to maintain the pH of the scouring solution at about pH 10, to prevent the hydrolysis of soap in the solution, to act as a salt to produce a concentration of soap molecules at the grease/solution interface, to satisfy the affinity of the wool fibre for alkali, and to neutralise some free fatty acids present in wool grease, thereby forming soap.

When used at normal concentrations and temperatures, sodium carbonate does not damage the wool fibres even though an aqueous extract from the scoured wool will have a pH of between 9 and 10.

**Soap**

Usually hard soap in the form of flakes is boiled up in water to form a stock solution which can then be added to the scouring process as required. The addition of sufficient soap helps to wet-out the wool by reducing the surface tension, emulsifies the grease, and maintains a stable emulsion.

**Synthetic detergents**

Biodegradable synthetic detergents may be used instead of soap and alkali; by this means it is possible to produce a neutral wool product and a neutral wool-grease by-product (which has enhanced value). This may be of particular advantage when scouring either (a) burry wool in order to avoid yellow staining of the wool from the burrs, or (b) if the wool is to be Vigoureux (melange) printed in order to avoid yellowing of the unprinted sections of the fibres during steaming.

**Heat**

This aids the formation of the scouring solutions and melts the wool grease ready for emulsification. Wool grease melts at about 38 °C and so in a four-bowl scouring set temperatures may range from 50 °C to 60 °C at the first main scouring bowl down to about 40 °C at the rinsing bowl.

Slightly lower temperatures may be used for cross-bred wools, and in the case of lustre wools and hairs such as mohair, the maximum temperature limit is about 40 °C in order to avoid a reduction of the natural lustre of the fibres.

**Agitation**

This means relative movement between the solution and the fibres, either by propelling the wool through the liquor, or vice-versa. Agitation is important because it provides improved contact between the detergent solution and the grease, and it provides mechanical forces which aid the grease removal. Excessive agitation can increase fibre entanglement, leading to subsequent fibre breakage, but insufficient agitation may leave dirt on the fibres.

**Time**

This is the ‘balancing’ agent: more time is needed if other agents are less active, and vice-versa. The average time for which fibres are immersed varies from about 4 to 9 minutes from entering the first solution to leaving the rinsing solution.

There is a wide variation in the details employed in scouring practice and there is no standard solution strength even for wools containing equal amounts of grease. The amounts of the chemical agents required vary according to the detailed constitution of impurities present in the wool being scoured; as an approximate guide Wira recommend 2 kg of soap and 3 kg of sodium carbonate per 100 kg of clean wool.

**Wool drying**

Wool leaving the squeeze rollers of a scouring set may have a moisture regain of about 65%, the actual regain depending on factors such as roller pressure, roller covering, wool quality, and wool/liquor temperature. It is necessary to reduce this to about 20% regain for subsequent processing or even lower for storage. Too much moisture may cause mildew, spontaneous combustion, or rusting of machinery, and may contribute to excessive nep formation in carding.

Hot air drying is normally used to remove most of the moisture; this may be supplemented by a radio-frequency dryer. A hot air dryer is shown at the far end of the scouring set in Plate 1.

The moisture-carrying capacity of air increases with temperature. Theoretically, therefore, a higher temperature should give more rapid drying; nevertheless dryers are normally operated with a temperature of about 82 °C in the middle section, with a higher temperature at the point of entry of the wet wool where the heat loss by evaporation keeps the fibres at a lower temperature.

The speed and efficiency of the drying process is largely dependent on the following factors:
Plate 1. Four-bowl wool scouring set. The fourth bowl delivers the wool fibres to the dryer at the far end of the line. The working width is 1.8 m and the overall width is about 3.35 m. The overall length of the scouring set is about 34 m. In addition there is a hopper feeder (not shown) and the dryer. A greasy input of 1500 kg/h could be sustained with this scouring set. Machines are also available with working widths of 0.9 m and 1.2 m, with production rates pro rata.Courtesy of Petrie & McNaught Ltd

(1) air temperature;
(2) rate of air circulation (m\(^3\)/min);
(3) the time for which the wool is exposed to the drying air;
(4) the state of the material to be dried (e.g. wool quality, thickness and even-ness of the fibre layer and its packing density);
(5) the direction of the air currents in relation to the wool.

There are two types of hot air drying machines in current use for wool drying: lattice dryers, and suction-drum dryers.

The thermal efficiency of a dryer may be expressed as 'specific steam consumption' in terms of the ratio kg of steam consumed/kg of water evaporated. Because of heat losses, modern lattice dryers may have a total specific steam consumption less than 2, and suction-drum dryers approach closely to 1.35 which is about equal to the essential heat required for evaporation. Older types of dryers used to have a total specific steam consumption of about 5 or 6.

It is unlikely that further developments in hot air dryers will bring about any great improvement.

Fundamental difficulties include the lack of homogeneity, bulk, and poor thermal conductivity of fibrous assemblies which cause thermal gradients, air channelling and slow heating. Although hot air drying is economical for loose fibres, it has the disadvantages of lack of precise control and local regain variations.

On its own, radio-frequency drying is uneconomic for scoured wool, but it can be used to follow a conventional dryer. The principle consists of passing the fibres between two electrodes subjected to a high frequency alternating voltage; this results in heat being generated within the material. A supplementary radio-frequency dryer following a hot air dryer delivers a product with less variation of moisture content and instantaneous control can be exercised. An essential feature is the provision of ventilation to remove steam produced during drying and to prevent condensation of liquid water on the relatively cold electrodes.

In worsted processing it is common practice to add about 0.5% of carding oil to the wool as it leaves the dryer, whereas in woollen processing oil is usually added to the fibres after they have passed through the blending process prior to carding.
Opening and cleaning

Raw cotton processing

Raw cotton impurities

An important difference between cotton processing and wool processing is that the natural wax found on cotton fibres is an aid to processing throughout all stages of cotton yarn manufacture, consequently normally it is not removed until the cotton has been processed into fabric form.

In addition to the wax, raw cotton contains a number of impurities, usually known collectively as ‘trash’. These impurities include those produced by the cotton plant itself, and those which originate in its habitat.

It is necessary to remove trash particles mechanically in order to facilitate processing and to obtain a satisfactory end-product appearance.

Types of cotton impurities include the following:

1. Sand, soil and dust. These are easy to remove because of their density and shape.
2. Whole seeds. These are smooth and fairly easy to remove even though they are small and light.
3. Broken seed down to small pieces of seed coat covered with fibre; these may be difficult to remove.
4. Undeveloped seed and broken fragments. These are tough, leathery, and difficult to remove. They cling to the cotton fibres and survive various mechanical treatments. In carding they may become ground up to form ‘fuzzy motes’.

The largest fuzzy motes consist of whole aborted immature seeds covered with very short lint fibres (i.e. fibres which stopped developing at a very early stage in their growth). Small fuzzy motes originate as either undeveloped or fully grown seeds which are broken in ginning and desintegrates still further in the opening, cleaning, and carding processes.

Another type of mote, known as a bearded mote, consists of a piece of seed-coat with fairly long lint fibres attached.

Both classes of mote become entangled with the cotton and their complete elimination is impossible except by combing.

Fuzzy and bearded motes which carry only a small piece of barely visible seed-coat are frequently termed seed-coat nepes.

5. Small seed fragments caused by faulty ginning or pest attack. These may survive the spinning process and form faults in the cloth; they produce yellow/brown stains if subjected to alkaline solutions.

6. Leaf fragments, and stalks. These have poor clinging power and their presence in yarn indicates poor cleaning efficiency in the blowroom.

Normally up to two-thirds of the trash removed in the blowroom may be of this type.

7. Short and immature fibres which are unsuitable for processing into carded or combed cotton yarns.

The amount and composition of trash depends on the grade and type of cotton. For example, a short low quality Indian cotton needs considerably more processing than a long staple high grade Egyptian cotton. Even within the nine American cotton grades there is a wide variation of trash contents, ranging from the best, known as Middling Fair which contains about 1.0% of trash, to the worst, known as Good Ordinary which contains about 9.8% of trash, with the middle grade, known as Middling containing about 3.1% of trash.

Removal of impurities from cotton

The removal of dust and trash is largely dependent on the degree of fibre individualisation which can be achieved in processing.

Most of the removal of impurities takes place in the blowroom, the objectives of which are to open, clean, blend and mix the fibres, and in conventional blowrooms to form a lap.

The name blowroom indicates that pneumatic transfer of fibres from one machine to the next is used by providing reduced air pressure near to the destination of the fibres.

Further removal of impurities takes place in carding and (if used) in combing, and there may be some dust removal at the drawframe. Tandem carding has been found to be particularly effective for the removal of fine dust and impurities for open-end spinning.

Blowroom opening and cleaning lines

Cleaning lines consist of from two beating points for synthetics up to about seven beating points for low grade cottons with trash contents exceeding about 3%. To enable more than one grade to be processed on a given cleaning line, some machines may be provided with a by-pass.

The minimum amount of beating to give sufficient opening is desirable; if opening could approach the single fibre state, then the cleaning efficiency of the blowroom would rise from the present 50 to 80% up to 95% with fewer machines.

However, intensive opening may create difficulties such as damaged staple and poor lap formation due to the fluffy state of the fibres. Cotton can be over-worked in the blowroom to the detriment of
Plate 2. Automatic bale opening for cotton. Up to 35 bales in a row may be traversed by the take-off unit to remove from 0.15 to 0.55 kg from each bale on each forward and each return traverse. Different bale heights are sensed and a microprocessor ensures equal run-out of a set of bales. During running, a new set of bales is laid out at the other side of the rail track and when one set of bales is used up, the take-off unit tower rotates 180° to commence on the new set. The continual feeding of uniform quantities of very small fibre tufts ensures good cleaning and blending. A single take-off unit can deliver 200 to 300 kg/h, depending on blend complexity. Courtesy of Rieter A.G.

Accurate feed control is required between each opening section to maintain a balance of production and constant processing conditions. This is done by doors which operate electrical switches when the pressures of cotton exceeds a predetermined amount, and accounts for the use of a few hopper feeders in a cleaning line. Photoelectric cells are also used to indicate the height of cotton in a hopper.

Blowroom methods of cleaning and opening

The actions used in the blowroom include one or more of the following:

Opposing spikes

These are found in bale-breakers, bale-openers, and hopper feeders. They usually give a rough pin action which breaks open large tufts of fibres to form smaller tufts. Closer settings usually give better opening and better mixing, but lower output. A higher speed, but thinner, feed may give good opening and maintain a reasonable production rate.
Beaters

These provide an important action and they are responsible, along with air currents, for removing almost all the impurities removed in the blowroom. It involves a mechanical means of releasing the particles of trash by striking heavy blows on the cotton. While being struck, the cotton may be impaled on spikes, may be held by rollers or a pedal/roller arrangement, may be in a restricted space between the beater and grid bars, or may be under the influence of air currents.

Air currents

Besides a sufficiently powerful fan to provide the air currents, it is also necessary to provide air-tight ducting and machine casings, pre-determined air entry places with the means of controlling the rate of airflow, means of separating the air and trash from the cotton, and a suitable air exit with filters to extract impurities collected by the air.

Separation of the cotton from the air-borne trash

There are three main methods of separating the cotton fibres from the trash particles and the air in which both are being conveyed.

The first involves drawing the air through the holes in a moving perforated surface; the fibres are collected by the screen, but some particles of trash pass through the holes along with the air. A higher speed of the screen gives a thinner film of cotton and therefore better dust separation. Perforated cages, condenser delivery boxes, and the Shirley wheel are types of delivery in which this principle is applied.

The second involves the diversion of the air currents. Well-opened cotton tufts have a high aerodynamic drag coefficient in relation to their mass, whereas trash generally has a low drag coefficient related to its mass. Aerodynamic drag forces will arise when there is a velocity difference between the material and the air current. When a loose tuft of cotton is subjected to a rapid horizontal deceleration, the high mass and virtually zero air-drag force on the trash enables it to be dislodged from the tuft of fibres.

The third method makes use of the different buoyancy of the fibres and trash under the influence of air currents and gravity. The cotton tufts are directed vertically downwards and a stream of air crosses this path horizontally. The near-zero drag force on the trash enables it to continue vertically downwards under the influence of inertia and gravity, whereas the air-drag on the fibres provides horizontal acceleration thereby separating them from the trash.

Blowroom lap formation

In conventional processing the delivery of the last machine in the blowroom, the scutcher, is in the form of a lap. Calendar rollers form a compacted sheet of cotton which is then rolled to form a lap wide enough to feed the following carding machine. The total lap may have a mass of 25 to 40 kg, a count of about 400 ktex, and a length of 60 to 100 m. Automatic doffing permits continuous running of the scutcher thereby increasing productive efficiency and reducing count variations caused by stopping and starting.

The lap form of delivery is still used in some factories although since the development of autolevelling there has been a trend towards pneumatic conveyance of fibres to the chute feeds of the carding machines.

Raw Flax Processing

Flax fibres occur in bundles embedded in the layer of pectinous gums which lie between the woody core and the outer bark of the flax plant stem, which achieves a height of up to 1.2 m. Each fibre is composed of a large number of ultimates which have a mean length of 33 mm and a mean diameter of 19 μm; the ultimates are cemented together by the same pectinous gums which permeate the whole fibre layer.

The bulk of the fibre bundles are inter-connected and form a network from root to tip, but the majority of forks are in the form of an upright ‘Y’ when the plant is standing; for this reason a short section of the root end is processed first in both hackling and scutching, allowing the remaining length to be processed towards the tip, thereby minimising the breakage of the bundles.

About one third of the stem is fibre, and the rest is made up of the woody core and the outer bark. The seeds are usually removed from the head of the plant mechanically before retting.

Retting

Retting consists of a fermentation process which decomposes the pectins which hold the fibre bundles, and it also rots the woody part of the stem so that it will break up and aid its removal. The process is complete when the fibre separates freely from the straw. Insufficient retting yields coarse, strong fibre which is hard to clean whereas excessive retting yields clean but weak fibres; hence it is preferable to err on the side of under-retting rather than over-retting.